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ABSTRACT

The third volume of the Global 2000 study presents basic information ("documentation") on the long-term sectoral models used by the U.S. government to project global trends in population, resources, and the environment. Its threefold purposes are: (1) to present all this basic information in a single volume, (2) to provide an explanation, in the words of the agencies and institutions themselves, of the structure of their models and the purposes for which their models were developed, and (3) to give a general sense of the individual sectoral models and the array of their documentation. Population, gross national product, climate, food, nonfuel minerals, and energy are the sectors focused on in this document. Inclusion was based on the fact that these projection areas used formalized methodologies and analytical models. As a result of this study, government data and models have been evaluated and weaknesses identified. Further, experts responsible for language analysis and modeling have been brought together to exchange knowledge and perspectives on global trends and to begin developing the capacity to produce interactive internally consistent projections. It has set the foundation for the construction of the type of foresight capability needed by the United States in the decades ahead. (NE)

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The Global 2000 Report to the President

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Documentation on the Government's Global Sectoral Models: The Government's "Global Model"

A Report Prepared by
the Council on Environmental Quality and the
Department of State
Gerald O. Barney Editor
and Study Director

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Volume Three

Preface

This third volume of the Global 2000 Study presents basic information ("documentation" as it is termed by modelers) on the long-term sectoral models used by the U.S. Government to project global trends in population, resources and the environment. These models were the basis of the projections developed for the Global 2000 Study.

Each of the sectoral models described in this Volume is a Government developed or Government endorsed model. Most of the models were developed directly by Government agencies. Three of the models—the GNP model, the nonfuel minerals demand model, and one of the population models—were developed by non-Governmental organizations, but have been applied or recommended by one or more Government agencies as being the best models available for the particular types of projections they provide.

Collectively, the sectoral models described in this volume are referred to throughout the Global 2000 Study as the Government's "global model." This term is more than a convenient means of reference. Collectively the sectoral models described here provide the U.S. Government with the same type of projections that other global models provide their users—projections of population, GNP, food, energy, minerals, water, environment, etc.

The Government's global model is different from other global models in several ways. First, the sectors of the Government's global model do not reside in a single computer but are located around Washington (and in other cities) in the computers of different departments and agencies, and non-Governmental organizations. The location of the sectors, however, is only a matter of convenience. All of the sectors—including those that are now only computational procedures performed with a calculator or adding machine—could be placed in a single computer without altering in any way their functioning.

An important way in which the Goverment's global model differs from other global models is that there are only very limited interactions among the sectors of the Government's global model. In most global models, the various sectors (food, population, energy, water, etc.) interact extensively. In the Government's global model intersectoral interactions are severely limited. Prior to the Global 2000 Study the primary mode of interaction among the sectoral models was not via a data channel or magnetic tape, but via the Government Printing Office (GPO). The departments and agencies made projections with their sectors of the Government's global model, and sent the results to GPO. Subsequently, GPO published a report. Other agencies then purchased the report and transferred the new sectoral projection into other sectors of the Government's global model.

It is important to recognize that when the Government departments and agencies designed or adopted the various sectors of the Government's global model, the sectors were not designed to be used as a well integrated, collective whole. Instead, it was assumed—implicitly or explicitly—that each sector (and department) acted more or less independently of the other sectors (and departments), and that the glacial interaction of the sectors through GPO was sufficient to insure the degree of internal consistency needed for the Government's global policy analysis. In recent years this assumption has come increasingly into question. Few knowledgeable analysts now believe it acceptable, for example, to assume each and every sector will have access to all of the land, energy, water, and capital that it may need, which is an assumption inherent in essentially every sector of the Government's global model, an assumption that follows directly from the lack of integration.

The Global 2000 Study was able to increase slightly the degree of integration in the Government's global model by accelerating and expanding somewhat the interactions among some of the sectors. This process first involved bringing people together. Prior to this study, not one of the persons ultimately responsible for the long-term global projections in any of the participating agencies knew anyone with a similar responsibility in any other agency. The Global 2000 Study identified these people, brought them together, and found ways to improve and increase the interactions among the sectors of the Government's global model. The results achieved —described in Volume 2, especially in Chapters 1 and 14—still fall far short of the interlinkages achieved in many other global models.

It is useful to contrast Volume 3 with the model analysis presented in Volume 2. Chapters 14–23 of Volume 2 were written by the Global 2000 central staff and reviewed by the agencies' modeling experts. These chapters describe briefly each of the agencies models, emphasizing aspects of the models that were important from the perspective of the Global 2000 mission. The purpose of Chapters 14–23 is to discuss the degree to which the Government's global model can be relied upon to produce a whole, internally consistent set of projections.

The purposes of Volume 3 are quite different. First, Volume 3 provides in a single volume the basic documentation on the Government's long-term global sectoral models relating to population, resources, and the environment. In some instances parts of these materials were also presented in Chapters 14–23 of Volume 2 and are repeated here to provide a complete volume of basic documentation.* Second, it provides an explanation, in the words of the agencies and institutions themselves, of the structure of their models and the purposes for which their models were developed. Third, it provides readers of the Global 2000 Study with access to the basic materials that were used in writing Chapters 14–23 of Volume 2. By reviewing the material in this Volume and the material in Chapters 14–23 of Volume 2, the reader will obtain a general sense of the individual sectoral models and the array (and, in some cases, disarray) of their documentation.

Information on some of the topics that should be covered in the Volume could not be obtained, and as a result there are several gaps. These gaps are of two kinds. First, the Global 2000 Study's projections for technology, fisheries, forestry, water, and the environment are not based on formal analytical models but rather on various other techniques of scholarly research, as described in Chapters 19 and 23 of Volume 2, and there is no "model documentation" for these sectors to present here.† This volume therefore focuses only on the population, gross national product, climate, food, nonfuel minerals, and energy sectors. Second, even in these sectors where formalized methodologies and analytical models were employed, there are occasional gaps in the available documentation. These gaps are discussed in the text that introduces the individual chapters.

To the fullest extent possible the documentation presented here is reproduced exactly as it was available to the Global 2000 Study team.§ As will be apparent from even a quick review, the documentation on the various sectors of the Government's global model is of mixed quality. If analytical models are to achieve even a fraction of their potential for aiding policy analysis and planning, the quality of documentation must improve, and so too must the extent and consistency of interactions among the sectors of the Government's global model.

The Global 2000 Study has made important strides toward these goals. The Government's data and models have been evaluated and their gaps and weaknesses identified. In addition, for the first time experts responsible for long-range global analysis and modeling within the Government have been brought together to exchange their knowledge and perspectives on global trends and to begin developing the capacity to produce interactive, internally consistent projections.

Thus the Global 2000 Study has set the foundation for the construction of the type of foresight capability that the United States will need increasingly in the decades ahead. The task of strengthening this foundation and building upon it should continue, ultimately drawing together the best of what the Government and the private sector have to offer in the field of long-term analysis. It is with this task in mind that the material in this Volume is presented in the framework of the Government's "global model."

A special note of thanks must be extended to Mr. Bardyl R. Tirana, Mr. Clifford McLean, and Mr. George Divine of the Defense Civil Preparedness Agency (later reorganized as the Federal Emergency Management Agency) for providing the funds for the preparation of this volume of the Global 2000 Study.

Gerald O. Barney
Editor and Study Director
January, 1981

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*In some instances the basic documentation for a particular model is printed in a volume containing other information. In these cases only the material most central to understanding the model is included here.

†The water projections are based in part on formal analytical techniques. The projections by Soviet hydrologist M. I. L'vovich are based on analytical methods described in the English translation of his work *World Water Resources and their Future,* National Technical Information Service, Springfield, VA, 1976, pp. 69–107. Unfortunately copyright laws prohibit reprinting the L'vovich methodology here.

§In one case some additional documentation became available after completion of the Global 2000 model analysis. Reference to this additional material is made in the text introducing the energy chapter.

Contents

PREFACE v

1 THE POPULATION SECTOR (BUREAU OF THE CENSUS) 1

- Introduction 1
- Population Projections 2
  - Introduction 2
  - Programs of Population Projections 2
  - General Issues and Principles 5
  - Methodology 7
  - Evaluation of Projections 34
- Projections Methods 38
  - Base-Year Data 38
  - Assumptions About the Future 38
- Sources of Base-Year Data and Projection Assumptions 41
  - People's Republic of China 41
  - U.S.S.R. 42
  - India 42
  - Indonesia 44
  - Bangladesh 45
  - Pakistan 46
  - Philippines 47
  - Thailand 48
  - South Korea 49
  - Egypt 50
  - Nigeria 51
  - Brazil 52
  - Mexico 53
  - Temperate South America 54
  - Northern America 55
  - Canada 55
  - United States 56
  - Japan 57
  - Australia 58
  - New Zealand 59
  - Eastern and Western Europe 59
  - Remainder of Continents 61
- Consistency Between Mortality Assumptions in Population Projections and Food Projections 63
- Bureau of the Census Projections to 2100 65
- New Bureau of the Census Projections for Eight Countries 67
- Bureau of the Census Comparison of Assumption by the Bureau and by the Community and Family Study Center 70

2 THE POPULATION SECTOR (AGENCY FOR INTERNATIONAL DEVELOPMENT/COMMUNITY AND FAMILY STUDY CENTER) 79

- Introduction 79
- A Prediction of World Fertility Trends During the Next One Hundred Years 80
  - Importance of Objectivity in Fertility Prediction 80
  - A Theory of Fertility: Post–1965 82

Assumptions Upon Which to Predict Future Fertility Trends 83
The Shape of Fertility Decline Curve 85
Predicted Fertility Trends: 1975–2075 88
Empirical Support for the Predicted Fertility Declines 89
Population Projections for the World: 1975–2000 92
Acknowledgements 93
Population Projections for the World: Individual Countries and Regions, 1975–2000 95
Conclusion 101
Community and Family Study Center Comparisons of Assumptions by the Center and by the Bureau of the Census 106

3 THE GROSS NATIONAL PRODUCT SECTOR 113

Introduction 113
The SIMLINK Model of Trade and Growth for the Developing World 114
Introduction and Background 115
The SIMLINK Approach 117
The Model in Detail 121
Assumptions 142
Results of Simulations 149
Appendix I: Basic Trade Data by Regions 150
Appendix II: Commodity Models 152
The Energy and Economic Growth Prospects for the Developing Countries 168
Preface 169
Introduction 169
Demand for Energy 173

4 THE CLIMATE SECTOR 174

Introduction 174
Methodology 175
Research Approach 175
Analysis of Data 177
Climate Scenarios 186
Appendix A: Climate Questionnaire 191

5 THE FOOD SECTOR 208

Introduction 208
Modeling the World Grain-Oilseed-Livestock Economy to Assess World Food Prospects 209
Model Structure 209
Alternatives Presented by the Model 211
Status of Modeling Effort 211
World Grain-Oilseed-Livestock Economy, 1985: Assumptions 212
World Grain-Oilseed-Livestock Economy, 1985: Results 214
Appendix 215
References 218
Alternative Futures for World Food in 1985: Volume I, World GOL Model Analytical Report 219
Introduction 219
Analytical Framework 221
Assumptions 223
Basis for Equations in GOL Model 238
Contributions to Analysis of World Food Problems 262
References 263
The Three Submodels 288

6 THE ENERGY SECTOR 289

- Introduction 289
- Methodology 290
  - Introduction 290
  - A Methodological Approach 290
  - Overview 292
  - Caveats and Assumptions 294
  - Iron and Steel, Other Manufacturing, Residential and Commercial 295
  - Model Parameter Estimates 298
  - Model Performance 298
  - OECD Demand Model Price and Income Elasticities 298
  - National Resource Estimates 298
  - Electric Utilities 302
  - Nuclear, Hydro, and Geothermal Generation 307
  - Synthetic Conversion Processes 308
  - Refining 308
  - Data Sources 313
  - Footnotes 314
- An Overview of the OECD Energy Demand Model 315
  - Introduction 316
  - Country and Product Information 318
  - Summary Model Description 320
  - Energy-GDP Ratio 323

7 THE NONFUEL MINERALS SECTOR 328

- Introduction 328
- Introduction [to *Mineral Facts and Problems*] 329
  - The Importance of Minerals in the U.S. Economy—1776–1976 329
  - Organization, Definitions, and Methodology of *Mineral Facts and Problems* Commodity Chapters 343
    - General Definition of Mineral and Energy Resources 343
    - Philosophic Basis for a Resource Classification 343
    - Glossary of Resource Terms 344
    - Areas of Responsibility and Operational Procedures 345
    - Forecasting Methods 346
    - Mineral Trends and Forecasts 350
    - References 361
  - Research Scheme 363
  - Excerpts from "World Demand for Raw Materials in 1985 and 2000" 367
    - The Research Scheme 368
    - World Economic Growth: The Prospect for 1985 and 2000 384
    - Intensity-of-Use 398

1 The Population Sector (Bureau of the Census)

Introduction

Two sets of population projections were developed for the Global 2000 Study, one by the U.S. Bureau of the Census (Census) and the other—at the request of the Population Office of the U.S. Agency for International Development (AID)—by the Community and Family Study Center (CFSC) at the University of Chicago.[1] The CFSC projections were included because they are used by the Population Office of AID to illustrate how effective, well-funded family planning programs might reduce world fertility. Documentation for the population model used by the Bureau of the Census is presented in this chapter. Documentation on the CFSC model is presented in Chapter 2.

Basic documentation for the Census population projection model is presented in the following section entitled "Population Projections."[2] This section describes several general methods by which the Bureau of the Census develops population projections, and describes specifically the cohort-component methodology which was used to develop the Global 2000 projections.

In addition to the general information on the cohort-component methodology, the Bureau of the Census prepared more specific and detailed information on the methods and assumptions used in developing the Global 2000 projections. This more specific information is presented here in two sections, "Projection Methods"[3] and "Sources of Base Year Data and Projection Assumptions."[4] The second of these two sections provides detailed rationale for the specific fertility, mortality, and migration assumptions that underlie the Census projections.

When the Global 2000 food projections were completed, they showed several countries in central Africa experiencing a significant decline in per capita food consumption. The Bureau of the Census was asked about the consistency of its mortality assumptions vis-a-vis the U.S. Department of Agriculture (USDA) food projections. Census replied by memorandum on December 15, 1977, indicating that, as best one can tell, the Census and USDA projections are consistent. The memorandum from Census is reproduced here.

The Bureau of the Census made a supplemental projection of world population through the year 2100 at the request of the Global 2000 study team. This projection assumes a continuation during the twenty-first century of fertility and mortality rates projected in the Global 2000 medium case for the year 2000. The results of these projections are presented here. It is interesting to note that the annual percentage increase in the world's population declines until the middle of the twenty-first century, and then *increases* somewhat as the still rapidly growing less developed country (LDC) populations become a higher percentage of the world's population. In this projection, the world's population approaches 30 billion by 2100, and the percentage of the world's population living in LDCs increases to 94 percent.

The Bureau of the Census has an ongoing program of updating its projections, and after the Global 2000 projections had been printed in Volume 2, Census developed some updated figures for a few countries and a new total for the world based on the updated estimates for the few countries. The world total projected for 2000 is about 3 percent lower in the new projections. The updated information is discussed briefly in Volume 1 of the Global 2000 Report and is presented fully here.

Finally, Census prepared several tables and graphs comparing its projections and assumptions with those of CFSC. These tables and graphs are presented in the last section of this chapter.

References

1. See *The Global 2000 Report to the President*, vol 2, pp. 7, 502.
2. "Population Projections," in Henry S. Shryock, Jacob S. Siegel, and Associates, *The Methods and Materials of Demography*, vol. 2, Washington: Government Printing Office, 1971, pp. 771–806.
3. "Projection Methods," in U.S. Department of Commerce, Bureau of the Census, *Illustrative Projections of World Populations to the 21st Century*, Washington: Government Printing Office, 1979, pp. 13-15.
4. "Sources of Base-Year Data and Projection Assumptions," Appendix B in ibid., pp. 95–116.

Editor's note: This section is Chapter 24 in Henry S. Shryock, Jacob S. Siegel, and Associates, *The Methods and Materials of Demography,* vol. 2, Washington: Government Printing Office, 1971, pp. 771–806.

Population Projections

INTRODUCTION

The Nature and Types of Population Projections

The distinction was made between projections and current estimates in the previous chapter. As may be recalled, current estimates make use of actual postcensal data from the recent past in the form of vital statistics, tabulations from population registers, or statistics that are merely correlated with population change. Where there are no such data, the current estimate reduces methodologically to a short-range projection; but even here account could be taken of qualitative information concerning, for example, a natural disaster, war, famine, epidemic, or mass migration. Conventionally, projections into the future make no attempt to speculate about such possibilities because they are essentially unforeseeable.

Although we think of projections as applying to future population, the projection may also be into the past. There is sometimes interest in historical figures for dates preceding the first census. One way of making such a "precensal" estimate is to project the population backward by essentially the same techniques that are used for making forward projections.

The distinction should be made between projections and forecasts.[1] When the author or the subsequent user of a projection is willing to describe it as indicating the most likely population at a given date, then he has made a forecast. At the other extreme, a model worked out to illustrate certain analytical relationships, on assumptions that are described as highly unlikely, would not be regarded as constituting a forecast of future population growth. It is apparent that, in this usage, all forecasts are projections but not all projections are forecasts.

Population projections, then, are essentially concerned with future growth. They may be prepared for the total population of nations, their principal geographic subdivisions, or specific localities within them. Projections may also be prepared for residence classes, such as urban and rural population and size-of-locality classes. The principal characteristics for which projections need to be made are age and sex. Projections may also be made for various social and economic subgroups of the population and for other demographic aggregates. The most frequently required and produced are projections of the population in terms of (1) educational characteristics (i.e., enrollment and attainment), (2) economic characteristics (i.e., economically active population, employment distributed by occupation or industry), (3) social aggregates like households and families. This chapter is concerned with projections of the total population of countries and their geographic subdivisions and with projections of the age and sex distribution in such areas. Other types of demographic projections are considered in appendix A.

Uses of Population Projections

The principal uses of population projections and other demographic projections relate to government or private planning. Demographic projections may be used directly or as the basis for preparing other more specialized types of projections. These include, for example, projections of the expected number of retirements from the labor force in a given period, and of the required number of teachers or classrooms, housing units, medical personnel and facilities, etc. The users include national and local governments, business firms, labor unions, university research centers, and social service organizations. A fairly detailed discussion of these uses and users is given in a recent publication of the United Nations.[2] The less advanced countries of the world have recognized the necessity of making concrete, comprehensive plans for achieving specific goals of public policy related to accelerating their social and economic development. A first step in planning is to study relevant aspects of the population and economy both at the present time and in the recent past. As the United Nations notes, "such study provides a basis for projections representing plausible future courses of development under the assumption that future conditions will evolve in an orderly manner from those of the present and past."[3] In addition to the uses in the field of planning, there are important uses in demographic analysis and related types of scientific studies.

PROGRAMS OF POPULATION PROJECTIONS

International Programs

Some of the international agencies have both compiled and published national population projections and made their own projections for the world and regions. They have provided

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[1] John V. Grauman, "Population Estimates and Projections" in Philip M. Hauser and Otis Dudley Duncan (ed.), *The Study of Population,* Chicago, University of Chicago Press, 1959, pp. 544–575; and Irving Siegel, "Technological Change and Long-Run Forecasting," *Journal of Business,* 26(3):146, July 1953.

[2] United Nations, *General Principles for National Programmes of Population Projections as Aids to Development Planning,* Series A, Population Studies, No. 38, 1965.

[3] Ibid, p. 2.

NOTE.—This chapter makes substantial use of Background Paper WPC/WP/454, *Projections of the Total Population and of Age-Sex Structure,* by Henry S. Shryock, Jr., and Background Paper WPC/WP/494, *Projections of Urban and Rural Population and Other Socio-Economic Characteristics,* by Jacob S. Siegel, both prepared for the United Nations World Population Conference, Belgrade, 1965.

leadership in many aspects of concepts and methodology and have published a number of instructional manuals.

The United Nations has published two comprehensive sets of population projections for the countries of the world, one in 1958 and another in 1966. The later report presented projections of the total population of the world, major areas, and regions for 1960 to 2000, and projections of the total population of each country for 1960 to 1980.[4] These projections take into account the results of censuses taken in many countries in 1960 and 1961. The 1958 report also presented projections of the future population of the world, regions, and countries, but on the basis of the censuses taken around 1950.[5] For various dates between 1954 and 1959, the United Nations also published rather detailed projections by sex and age groups for certain regions and countries, particularly in Central and South America and Asia.[6] Earlier, the League of Nations had sponsored the publication of a set of comparable projections for the countries of Europe and the Soviet Union.[7]

Projections for groups of individual countries have been compiled by various international regional agencies – OEEC (OECD), IASI, ECLA, CELADE, the Caribbean Comission.[8] The regional Demographic Training and Research Centers of the United Nations, which may work in cooperation with various national agencies or universities, have produced sets of projections for some of the countries in their region. For example, CELADE, which is jointly sponsored by the University of Chile, has published projections for many countries of Latin America.

Other sets of projections for groups of countries have been prepared by individual governments or private organizations or offices.[9] The United Nations has not presented in the *Demographic Yearbook* a compilation of population projections made by national agencies.

Comparability. – International agencies have not made direct recommendations regarding the specific form and methodology of projections to their member countries, or set standards of the type found in the case of censuses and vital statistics. The United Nations has set down some guiding principles, however, noting that "both the requirements of population projections and the available resources to satisfy these needs differ from country to country, and uniform prescriptions would not be suitable for all countries; therefore, . . . guiding principles . . . are formulated in such a way that they can be adapted in each country to national needs and available resources. These principles will also help to achieve as much international comparability of projections as is compatible with existing differences in national needs and resources." [10]

The national projections prepared by national agencies have been assembled in unified reports issued by international organizations on various occasions, and these sets of projections have followed common guidelines in varying degrees.[11] The national projections made according to a common set of assumptions and methodology by a single agency or office are much more likely to be comparable, however.[12] Even here, however, comparability is affected by differences in the availability and quality of the basic national data. In fact, a uniform methodology tends toward the least common denominator of what is available. The dilemma then is whether to have more regard to uniformity or to the inclusion of those individual projections that are noteworthy for sophistication of assumptions, data, and methodology. The most recent study of world population prospects by the United Nations attempts to embrace the best features of both approaches.[13] The population models developed at the United Nations also provide a unifying framework for assumptions concerning future trends in the components of population change. Underlying these models, there seems to be a theory of demographic transition, although Grauman and others have characterized the demographic transition as one of the discredited laws of population growth.[14] In a very general way, there does seem to be such a phenomenon although demographic changes in a given country may not conform very closely to any of the models.

National Programs

The best sources for the population projections prepared by national governments are the publications of the governments themselves. As was mentioned in the preceding section, some of these projections have been included in international compilations although in these compilations they have often been abridged in detail or even adjusted in some fashion in the interests of comparability. The scope of national population projections programs varies enormously in respect to resources devoted to them, frequency and detail of the projections, and the kind of publication, including the extent of the explanation of the methodology and assumptions, the analysis of the results, and the interpretation of the future trends implied.

As far as the calculations themselves are concerned, the methodology, computational procedure, and the detail of the resulting figures will depend upon a number of factors, including particularly the needs of the national government and of various sectors of the general public (which will affect the resources to be devoted to a program of population projections), and the availability of time, basic data, trained demographers, electronic computers, and competent programmers. Rather elaborate sets of projections from the standpoint of the number of different series published were made even in the days before the electronic computer, however. The 16 series of projections made in the 1940's for the Royal Commission on Population (Great Britain) were all done on desk calculators, as were the 12 series of U.S. projections made by Thompson and Whelpton for the National Resources Planning Board.[15] Nowdays, the elaboration of the work is likely to come in terms of the specificity of the "input" data (disaggregation in terms of race, marital status, parity, cause of death, etc.) and the detail of the "output" data rather than solely in the number of combinations of assumptions.

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[4] United Nations, *World Population Prospects as Assessed in 1963*, Series A, Population Studies, No. 41, 1966.

[5] United Nations, *The Future Growth of World Population*, Series A, Population Studies, No. 28, 1958. Earlier sets of world population projections were published by the United Nations in "The Past and Future Growth of World Population – A Long-Range View," *Population Bulletin*, No. 1, 1952, and "Framework for Future Population Estimates, 1950–80, by World Regions," *Proceedings of the World Population Conference, 1954* (Rome), Vol. III, 1955.

[6] United Nations, *The Population of Central America (including Mexico), 1950–80*, Series A, Population Studies, No. 16, 1954; *The Population of South America, 1950–80*, Series A, Population Studies, No. 21, 1955; *The Population of South-East Asia (including Ceylon and China: Taiwan), 1950–80*, Series A, Population Studies, No. 30, 1959; and *The Population of Asia and the Far East, 1950–80*, Series A, Population Studies, No. 31, 1959.

[7] Frank W. Notestein *et al.*, *The Future Population of Europe and the Soviet Union: Population Projections, 1940–70*, Geneva, League of Nations, 1944.

[8] Organization for European Economic Co-operation, *Demographic Trends in Western Europe and in the United States, 1956–76*, Paris, 1961; Organization for Economic Co-operation and Development, *Demographic Trends in Western Europe and North America, 1965–80*, Paris, 1966; Interamerican Statistical Institute, Panamerican Union, *America en cifras, 1969: Proyección de la población por sexo y grupos de edad, 1961–81 (America in figures, 1969: Projection of population by sex and age, 1961–81)*, Washington, D.C., 1969; Caribbean Commission, *The Demographic Problems of the Area Served by the Caribbean Commission: Projections*, prepared for the Technical Conference on the Demographic Problems of the Area Served by the Caribbean Commission, Port of Spain, Trinidad, July 25–Aug. 2, 1957.

[9] France, Service de cooperation, Institut national de la statistique et des études économiques, *Perspectives de population dans les pays africains et Malgache d'expressión française; Étude de synthèse des enquêtes démographiques récentes (Projections of population in the French-speaking countries of Africa and the Madagascar region)*, Paris, December 1963; U.S. Bureau of the Census, *International Population Reports*, Series P-90 and P-91; Nathan Keyfitz and Wilhelm Flieger, *World Population: An Analysis of Vital Data*, Chicago, Ill., University of Chicago Press, 1968; and Nathan Keyfitz and Edmund M. Murphy, *Comparative Demographic Computations*, Population Research and Training Center, University of Chicago, Chicago, Ill., 1964.

[10] United Nations, *General Principles for National Programmes of Population Projections as Aids to Development Planning*, p. 1.

[11] See, for example, Organization for European Economic Co-operation, op. cit.

[12] France, Institut national de statistique et des études économiques, op. cit.; Keyfitz and Flieger, op. cit.; Keyfitz and Murphy, op. cit.; Notestein *et al*, op. cit.; various United Nations publications cited.

[13] United Nations, *World Population Prospects as Assessed in 1963*, pp. 44–45.

[14] Grauman, op. cit., p. 551.

Many countries have recently produced their first official population projections, often as a basis for their formal plan of economic development. Other countries have previously produced one or more sets of projections and their program involves updating the figures from time to time, taking account of the rapidity with which the demographic situation is changing and particularly the suspected occurrence of a turning point in previous trends. Some countries change their projections at frequent intervals if they are repeatedly getting out of line with actual demographic developments.

Although virtually never does more than one national agency in a country take a census or register vital events, it is not unusual for more than one agency to prepare the same type of population projections or projections of such demographic aggregates as the labor force, the population attending school, or skilled manpower. In other countries, several agencies may have a division of labor with regard to these different kinds of projections. In still other countries, the responsibility for preparing official projections of various kinds may have been assigned to a single agency. Sometimes the work of preparing official projections may be contracted to a person or organization outside the national government. An example of such an arrangement involving an international agency was mentioned above (i.e., League of Nations).

The projections differ from one country to another as to the method employed. This method may often involve the separate projection of the components of migration, births, and deaths, particularly where adequate vital statistics are available. For a given country alternative projections may be derived with different assumptions as to migration, or fertility, or mortality, or a combination of these components.

Tables 24-1 and 24-2 provide illustrations of official projections published by national agencies in the less developed countries. Table 24-1 gives a summary of projections for Pakistan according to three assumptions regarding future fertility after 1960—(I) constant fertility; (II) constant fertility until 1970, then 30 percent linear decline to 1985, constant thereafter; (III) constant fertility until 1965, then 50 percent linear decline to 1985, constant thereafter. Panama's projections also employed three fertility assumptions after 1960—(I) increasing fertility, (II) constant fertility, and (III) decreasing fertility (table 24-2). Projections of age-sex distributions usually accompany projections of the total population in national reports. Less commonly, the reports include projections of various characteristics of the population, such as urban and rural and economically active populations.

Table 24-1.—Projections of the Population of Pakistan by Sex According to Three Assumptions Regarding Fertility: 1965 to 2000

[In thousands. Midyear population]

Sex and assumption	1960	1965	1970	1975	1980	1985	1990	1995	2000
BOTH SEXES									
Assumption I..................	97,720	113,948	134,939	163,027	200,009	247,254	305,767	378,718	470,546
Assumption II.................	97,720	113,948	134,939	159,696	188,328	219,903	258,704	305,141	359,413
Assumption III................	97,720	113,948	131,667	151,582	172,984	193,810	218,515	246,471	276,874
MALE									
Assumption I..................	50,455	58,881	69,652	83,963	102,746	126,728	156,476	193,618	240,421
Assumption II.................	50,455	58,881	69,652	82,261	96,764	112,714	132,359	155,915	183,478
Assumption III................	50,455	58,881	67,981	78,107	88,906	99,346	111,770	125,858	141,197
FEMALE									
Assumption I..................	47,265	55,067	65,287	79,064	97,263	120,525	149,291	185,100	230,125
Assumption II.................	47,265	55,067	65,287	77,437	91,564	107,189	126,345	149,226	175,935
Assumption III................	47,265	55,067	63,686	73,475	84,078	94,464	106,745	120,613	135,676

Source: Adapted from, Pakistan Institute of Development Economics, *Population Projections for Pakistan: 1960-2000*, by Lee L. Bean, Masihur Rahman Khan, and A. Razzaque Rukanuddin, Karachi, January 1968, table V, p. 28.

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[15] United Kingdom, Royal Commission on Population, Papers of the Royal Commission on Population, Vol. II, *Reports and Selected Papers of the Statistics Committee*, London, H.M.Stationery Office, 1950; and U.S. National Resources Planning Board, *Estimates of Future Population of the United States, 1940-2000*, by Warren S. Thompson and Pascal K. Whelpton, August 1943.

Table 24-2.—Percentage Distribution by Broad Age Groups of the Projected Male and Female Population of Panama, According to Three Fertility Assumptions: 1960 to 1980

Age group	Male					Female				
	1960	1965	1970	1975	1980	1960	1965	1970	1975	1980
ASSUMPTION I										
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Under 15 years	43.32	43.98	45.07	46.04	46.72	43.59	44.14	45.03	45.85	46.41
15 to 44 years	41.48	40.67	39.82	39.38	39.39	41.78	41.16	40.40	39.98	39.91
45 to 64 years	11.67	11.72	11.59	11.04	10.19	11.03	11.02	10.96	10.62	10.02
65 years and over	3.53	3.63	3.52	3.54	3.70	3.60	3.68	3.61	3.55	3.66
ASSUMPTION II										
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Under 15 years	43.32	43.90	44.81	45.49	45.88	43.59	44.08	44.78	45.31	45.57
15 to 44 years	41.48	40.72	40.00	39.78	39.99	41.78	41.21	40.58	40.38	40.52
45 to 64 years	11.67	11.74	11.65	11.15	10.37	11.03	11.03	11.01	10.73	10.18
65 years and over	3.53	3.64	3.54	3.58	3.76	3.60	3.68	3.63	3.58	3.73
ASSUMPTION III										
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Under 15 years	43.32	43.80	44.44	44.71	44.69	43.59	43.97	44.40	44.54	44.38
15 to 44 years	41.48	40.79	40.27	40.35	40.84	41.78	41.29	40.86	40.95	41.38
45 to 64 years	11.67	11.76	11.73	11.31	10.62	11.03	11.05	11.09	10.88	10.43
65 years and over	3.53	3.65	3.56	3.63	3.85	3.60	3.69	3.65	3.63	3.81

Source: Adapted from, Panamá, Dirección de estadística y censo, *Estadistica Panameña, Supplement, El crecimiento de la población Panameña en el periodo 1950 a 1980* (Growth of the population of Panama in the period, 1950 to 1980), by Vilma N. Médica, Panamá, 1966, table 42, p. 54.

Programs of State and Local Governments and of Private Organizations

In some countries, where many planning activities are carried out by state (or provincial), regional, metropolitan, or local agencies, a very large number of demographic projections may be produced and even published. These vary greatly in sophistication and form of presentation. Universities, private research institutes, and business organizations have added to the volume of available projections. An indication of the kinds of State and local agencies in the United States that prepare population projections was obtained as a by-product of an inventory conducted by the Bureau of the Census regarding programs of current population estimates.[16]

The pioneering work of Warren S. Thompson and P. K. Whelpton of the Scripps Foundation in developing the component method has had an enormous influence on subsequent work around the world. Their projections for the United States were adopted as the official U.S. Government projections in the 1930's and early 1940's; however, by the midforties the method and the official responsibility for preparing projections were taken over by the Bureau of the Census. The Scripps Foundation returned to this field in the late fifties and sixties when Whelpton and his associates developed projections of the U.S. population on the basis of fertility "expectations" data obtained from the Growth of American Families Studies. In an earlier generation, the logistic curve, promoted by Raymond Pearl and Lowell J. Reed of Johns Hopkins University, was a tool widely used by demographers and others in the projection of future population growth, both in the United States and abroad (ch. 13).

GENERAL ISSUES AND PRINCIPLES

The Framework of Assumptions

Basic Assumptions.—It is almost commonplace to preface published projections with a statement that it is assumed that the area will not be visited by a war or a natural disaster. Furthermore, no attempt is made ordinarily to allow for future economic fluctuations of a cyclical nature. Of course, the age-sex structure of the population, the marital status and cumulative fertility of its women, and other measures of its current demographic status reflect the impact of such events in the past. The reports presenting the projections do sometimes state that conditions of nearly full-employment are expected to continue or that the gross national product is expected to increase at a given percentage per annum—even though relatively little is known about how variations in these economic phenomena affect population growth.

Number of Series and Combination of Assumptions.—Because of the evident uncertainties regarding future population changes, it is desirable to present more than one series of projections, in the case of both national projections and subnational projections. These may represent combinations of multiple assumptions concerning one or more of the components of population change. For example, there may be high, medium, and low assumptions for mortality and fertility. The high assumption may represent constant mortality or fertility; or all assumptions may call for decline and the variations may relate only to the date of onset or the rate of decline. In our era, increases in these components are regarded as very unlikely in many countries.

The various combinations of assumptions regarding fertility, mortality, and migration may give rise to a very large number of series of population projections. The 16 projection series published by Great Britain's Royal Commission on

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[16] U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 328, "Inventory of State and Local Agencies Preparing Population Estimates: Survey of 1965," March 8, 1966.

Population, mentioned above, were chosen from 250 possible combinations. All the published projections were described as reasonable possibilities; the other combinations were not worked out became particular levels or trends of mortality did not seem compatible with particular levels or trends of fertility. Thus, it would be very unlikely that expectation of life at birth would rise to 70 and continue at that high level while fertility remained constant, say at a total fertility rate of 6.0. Such combinations have never been observed in demographic history; and they would imply remarkable inconsistencies with regard to modernizing developments in the fields of medicine, public health, economic development, and attitudes toward marriage and the family.[17]

One series may be designated as "most probable" or as a "best judgment" series. This usage indicates that an effort is being made to "forecast" and not just to "project." The medium or central series is ordinarily taken to be the most probable series. If only three series are prepared, the distribution of the high and low series about the medium series does not have to be symmetrical, but the usefulness of the projections is enhanced if the series are at least roughly symmetrical. The range from the highest to the lowest of the "reasonable" series presented may be regarded as a rough indicator of the degree of uncertainty regarding future population change. It is doubtful whether the range should be interpreted in a probability sense, however. (See the discussion below of the accuracy of projections.) One series may usefully be included in a set of projections which represents a "continuation of current levels." When we apply this general assumption to fertility, we have to choose among the several ways of measuring the level of fertility as well as the calendar year or group of years which is "current."

Principal and Analytic Series.—The series we have just described may or may not all represent reasonable possibilities. Assumptions or combinations of assumptions regarded as very unlikely of attainment may be presented for their analytical value or to set an upper or lower limit within which population growth is virtually certain to remain. Series I of the projections made for the United States in 1958 represents an example of the latter type.[18] Another example is provided by the projection series for South Korea that was based on the assumption of the continuation of current mortality and fertility levels. The report noted that the assumption is not realistic, but it was included because it provided a useful benchmark against which to measure the effects of declining mortality.[19] The difference between the series allowing for declining mortality and the model analytic series assuming constant mortality would represent the effect of declining mortality.

As suggested above, in these and other examples, certain series may be characterized as reasonable possibilities and others as unreasonable possibilities. A more explicit way of distinguishing the two kinds of projections is to include some or all of the former as "principal series" in the regular tables of the published report and to place the latter in an appendix as "analytic series," including any series that were elaborated simply to serve as a benchmark for the other series. An appendix may also include reasonable series which represent intermediate assumptions, series derived by a method that still may be at an experimental stage, etc.

Length of Projection Period

Projections may extend for varying numbers of years into the future depending upon the type of area in question, the needs to be served, the conception of the problem by the analyst, and the available resources. Projections made nearly a century ahead by the U.S. Social Security Administration, as a basis for the long-range cost estimates of the social security system of the United States, represent one extreme.[20] The projections for Great Britain made for the Royal Commission on Population also extended a century ahead, covering the period 1947 to 2047. Projections of just a few years used for short-term economic analysis represent the other extreme. Long-term projections (over 25 years) are needed in connection with the development of water and forestry resources, major transportation and recreational facilities, and planning for provision of food, whereas only middle-range projections (10 to 25 years) are required for planning educational and medical facilities and services, and housing needs. Relatively simple methods may be used both for short-range projections (under 10 years) and for the extensions of middle-range projections beyond 25 years. For projections up to 25 years ahead the more elaborate methods are usually employed and are recommended. Differences in the accuracy of national and subnational projections suggest that, in general, the latter be extended for substantially fewer years into the future (see below).

Frequency and Nature of Revision

There is, in general, a real problem as to how often an organization should revise its projections and how fundamental the changes should be. Primary factors pertinent to these decisions include: (1) The extent to which the present projections are out of line with current estimates, (2) the mere passage of time, say a few years, during which at least some of the series of projections must deviate from the current estimates, (3) the availability of additional data, not only for more recent periods but also (more refined data) for earlier years, (4) advances in methodology. Secondary factors include (1) the availability of resources and (2) the need to meet an established publication schedule. The revision may consist of merely "splicing in" adjusted projections for the next few years or of making a small absolute or ratio adjustment of all the original projections, in order to make them consistent with newly available current data. In such cases the basic assumptions are not otherwise modified. In other cases, the most recent data may suggest the need for major modifications in the basic assumptions and hence a recalculation of all the projections.

Detail of Presentation

National reports on population projections will differ greatly in the detail shown, but they should be fully informative as to how the projections were made. In addition to the principal series, the report may usefully present a number of supplementary series, including additional combinations of the basic assumptions and analytic series. Single ages or broad age groups and annual or quinquennial figures may be presented, depending on the quality and need for the figures. When there are many series, the age or chronological detail may be abridged for those series that are not considered the principal series. The text should fully discuss the choice of assumptions, the methodology, the resulting projections, and even their implications. It is useful also to present the relevant information on the past trends of the components of population change which were taken into account in choosing the assumptions, the implied birth and death rates at future dates, and other demographic summary measures.

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[17] United Nations, *World Population Prospects as Assessed in 1963*, pp. 47–48.

[18] U.S. Bureau of the Census, *Current Population Reports*, Series P–25, No. 187, "Illustrative Projections of the Population of the United States, by Age and Sex: 1960 to 1980," Nov. 10, 1958.

[19] Republic of Korea, Economic Planning Board, *The New Population Projections for Korea: 1960–2000*, Seoul, 1964, p. 39.

[20] U.S. Social Security Administration, Office of the Actuary, "United States Population Projections for OASDHI Cost Estimates," by Francisco Bayo, *Actuarial Study No. 62*, December 1966.

METHODOLOGY

Some Methodological Principles

From the above discussion of principles, several conclusions, or indeed recommendations, regarding methodology emerge. The choice of methods, although affected by the other considerations mentioned, should be determined primarily by the data available. The availability of adequate statistics on the age-sex distribution of the population and of adequate statistics on age-sex-specific fertility and mortality ordinarily calls for a cohort-component method. Using theoretical models, the cohort-component method may also be employed without benefit of recorded age detail for fertility and mortality. Even if there are some defects in the basic data, however, it may often be advisable to adjust the data rather than to have recourse to a more theoretical model. More time may then need to be spent on evaluating and adjusting the basic data than on computing the projections.

The trend toward refinement of the methodology of population projections has led to increased specificity of the assumptions and the estimation categories on the ground that more accurate assumptions can be made for those more specific categories. The impetus toward specificity derives in part from the thesis that the quality and usefulness of projections will be enhanced by employing a method whose steps parallel the order of events in real life. This principle leads to the use of methods based on birth or marriage cohorts and specific rates for the frequency of events affecting these cohorts as they progress through life. In its fully developed form we have a population model.

In order to take advantage of the most up-to-date knowledge of recent events, the benchmark of the projections should be the latest postcensal estimates (including sample survey estimates) or, failing that, the latest census counts. There would ordinarily be only one set of population figures at the benchmark date; however, if the current estimates are subject to considerable error, including sampling error, a range of estimates may be employed. For later dates, there should be at least two principal projection series. Moreover, the various series in a single set of projections should conform to some general system of projections, permitting easy comparison of the assumptions and results. Finally, the assumptions of each principal series should be mutually consistent and should not represent an unreasonable combination of developments.

Classification of Methods

The methods of making projections may be classified in a number of different ways. One possible way is to distinguish those that can be applied independently to any type of area from those that are dependent on or require antecedent projections for other areas. The latter class of methods includes (1) summing of projections, as in the case of adding country projections to secure regional or world population totals, (2) obtaining a projection for one area on the basis of changes in some other similar area or more inclusive area for which a projection is already available. The latter procedure covers a wide range of techniques; e.g., distributing the projected population of an area among its subdivisions taking account of the past proportionate distribution (ratio methods) and projecting the components of population change for an area on the basis of changes in these components for a similar area or more inclusive area for which such projections are already available. Most typically, the independent methods are applied in the case of national populations, but they could be employed to project the population of any type of area from the world total to a particular locality. These methods include mathematical methods and component methods applied at any geographic level, but particularly at the national level. Even here the results over a number of areas may be adjusted to population figures for a parent area. In fact, it is a principle of population projections to extend the degree of interdependence where possible to assume consistency of assumptions and results for the various areas for which projections are being prepared.

Another typology of the methods distinguishes among mathematical and ratio methods, various methods using a series of indicators of population change, component methods, and combinations of these. The mathematical methods employ relatively simple mathematical equations to describe the nature of future population change of an area, taken as a whole. The component methods involve the separate projection of mortality, fertility, and net migration. The methods using indicators of population change embrace a variety of procedures, some estimating total population directly, others estimating net migration only, which is then combined with a separate estimate of natural increase. The indicators (e.g., employment, per capita income, etc.) may be used to project population or net migration by a regression or a ratio procedure.

The description of methods will begin with those methods applicable to national populations. It is convenient to consider the projection of the age-sex distribution of national populations at the same time because the totals are often obtained by summation of projections for age groups. Projections for the principal geographic subdivisions of countries are then considered. Again, projections of the age-sex distribution for such areas are considered at the same time. As mentioned earlier, projections for certain social and economic subgroups of the population, including urban and rural groups, the enrolled population, and the labor force, and for social aggregates like households and families, are considered in appendix A. These are often derived from prior population projections for the area containing the subgroups, but the process may be reversed, with the projection for the total population being obtained by summation over a set of projections for the subgroups or by ratio estimation from the projections for social aggregates.

National Projections of Total Population and Age-Sex Composition

Methods of preparing national projections of total population fall very simply into two classes, mathematical methods and component methods. As is indicated later, the component method is usually the method of choice, but there are many variations of the component method and results may differ substantially from one variation to another. Mathematical and component methods may also be employed as principal methods of preparing projections of age-sex distribution for countries. They may be combined with ratio procedures as subsidiary elements in the method; as, for example, when the percent distribution of a population by age is projected by a mathematical formula. The component method is also the method of choice for preparing projections of age-sex distribution; this is so even when very limited historical data on components or component data of doubtful quality are available. In the latter situation, these data must first be corrected before the actual projections are calculated.

Mathematical Methods.—Mathematical methods are simplest conceptually, usually require relatively little time to apply, and historically antedated the use of component methods. The mathematical methods involve application of some mathematical formula directly to the total population from one or more censuses, to derive projections of total population. The mathematical equations useful for preparing projections correspond to those described in chapters 13 and 22 for measuring population change or for extrapolating time series. The number of mathematical forms that could be used to project population could be extended far beyond those cited there, but very few of these are actually employed. For projecting total population, polynomial forms, including linear extrapolation, have little application, especially over the long-term. Various exponential forms are widely used, however. These include the geometric curve, with (1a) annual or (1b) continuous compounding, and (2a or 2b) the logistic curve.

$$P_t = P_o(1+r)^t \qquad (1a)$$

or

$$P_t = P_o e^{rt} \qquad (1b)$$

$$P_t = \frac{\frac{1}{a}}{1+\frac{b}{ae^{-rt}}} \qquad (2a)$$

or

$$P_t = \frac{K}{1+e^{a+bt}} \qquad (2b)$$

where r is the growth rate, t is the number of years, a and b are constants, and e is the base of the natural system of logarithms. In (2), the constant $1/a$ or K is the upper asymptote.

For making a population projection, one may apply equation (1a) or (1b) either by using the latest intercensal rate of change, the average rate over a longer period, or an arbitrary rate, or by fitting a curve by the method of least squares to a series of census totals. Since growth rates are likely to change in the long term, these formulas are recommended for use only in making short-term projections.

Fitting a logistic curve is a more complicated procedure and requires a greater number of observations covering a longer period. At the same time, it is useful for projection over a greater period of years than the simple geometric procedures, particularly if the past series has reached the point of inflexion. This form of projection overcomes a principal weakness in the use of the geometric rate, namely, the possibility of obtaining extremely large population figures after a short period. The logistic growth model has a finite upper limit with steadily decreasing rates of growth. The logistic curve occasionally seems to fit the growth history of a country, or at least a segment of a country's growth history, and hence should be applicable to projections for these countries. It has, in fact, been employed to make projections for a number of countries, especially in the Americas and in the years before World War II.[21] The difficulty is to select the countries and the periods in the countries' history. The procedure for fitting a logistic curve to a series of population totals was described in chapter 13. A simple extension of this procedure provides the desired projections. Like all mathematical curves, the logistic is quite mechanistic; hence, it may be advisable not to apply it over too long a period.[22] The logistic cannot be used to project a population that is decreasing.

Mathematical methods are now much less frequently employed to estimate the population of countries than formerly, even though they have by no means been abandoned.[23] Component methods have been displacing the mathematical methods.

Component Methods.—These methods involve the separate projection of mortality, fertility, immigration, and emigration. As in preparing population estimates, the last two components are usually combined in the form of net migration; and even this combined component is often omitted, in effect, by use of an assumption of "no net migration." Since the method may be easily applied, and is conventionally applied, by age-sex groups, projections of age-sex structure are usually obtained directly by this method; and total population is commonly obtained by combining the projections for age-sex groups. The component method makes explicit the assumptions regarding the components of population growth and hence can give one considerable insight into the way population changes. Valuable by-products, such as various measures of fertility and mortality, as well as estimates of the effect of alternative levels of fertility, mortality, or immigration on population growth, may also be obtained. In its simpler form the component method is mechanistic in many ways. In its more complex forms, however, the component method becomes a rather elaborate model of population growth (see ch. 22, "Demographic Models"). For example, the assumptions can be expressed in the form of probabilities simulating human behavior, i.e., to each member of the population can be attached a probability of marrying, giving birth, migrating, or dying within a given interval of future time. Because the probable error associated with the projection of each component may be rather large, the component method is not necessarily more accurate, on the average, than the mathematical methods.

Use of crude rates.—In principle, crude birth and death rates may be employed as measures in projecting the numbers of births and deaths. They are rarely used in a direct fashion for this purpose, however, since they are strongly affected by the structure of the population, particularly its age-sex structure. Crude rates have been employed occasionally in otherwise elaborate studies of the future on the ground that methodological refinement is unjustified by the state of our knowledge.[24] Assumed absolute numbers have not been used for projecting births and deaths, but such an assumption is sometimes made for the migration component.

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[21] Irene B. Taeuber, "The Development of Population Predictions in Europe and the Americas," *Estadistica*, II:323–346, 1944.

[22] György Acsádi and Emil Pallós, "Methods for Population Forecasts," *Demográfia* (Budapest), 1(1):68–94, 1958; and John Hajnal, "The Prospects for Population Forecasts," *Journal of the American Statistical Association*, 50(270):309–322, June 1955.

[23] Luigi Amoroso, "Le quattro fasi di espansione demografica" (The four phases of demographic development), *Rivista di politica economica*, 48(11): 1168–1175, November 1958; and H. C. Plessing, "Om den Logistiske Kurve og dens Anvendelse i Praksis" (On the logistic curve, its use and practice), *Erhversekonomisk Tidskrift* (Copenhagen), 26(3):205–231, 1962.

[24] Marion Clawson *et al*, *Land for the Future*, printed for Resources for the Future, Inc., by the John Hopkins University Press, Baltimore, 1960.

Cohort-component methods.—In these methods, the computations are carried out separately for age-sex groups on the basis of separate allowances for components. Specifically, one starts with the population distributed by age and sex at the base date, applies assumed survival rates and age-sex specific fertility rates or birth probabilities, and makes allowances for net migration by age and sex, if desired. The base population should be the latest dependable postcensal estimates of the national population distributed by age and sex. In the event that current estimates are not available or calculable, the data from the last census can be used. The age groups usually have 5-year class intervals. Five-year life-table survival rates can be applied to this base population, to bring it forward 5 years at a time and to allow for deaths in the interval, by 5-year age cohorts. Births are usually computed by applying 5-year age-specific fertility rates to the women of childbearing age at the middle of each 5-year time interval. (The actual measure used to project fertility may be quite different but, typically, this measure is converted into age-specific fertility rates in order to derive the actual number of births.) The schedules of fertility and mortality rates are either held constant through all, or part, of the projection period or are allowed to change according to specified formulas, which may vary from the very simple to the quite complex. On the other hand, the projection scheme may be rather informal and quite arbitrary. In any case, the determination of the prospective changes in fertility and mortality involves a considerable element of judgement.

Projections of Mortality.—In projecting the component of mortality, two measures of mortality may be employed, age-specific death rates or age-specific survival rates; hence, our discussion will be concerned principally with the different ways of projecting rates of these types. If the projections of mortality are carried out initially in terms of age-specific death rates, they will have to be converted into survival rates so that they can be applied to the population in terms of age cohorts.

Projections of past trends.—Where there are adequate mortality statistics for the country itself, we may start with the country's own age-sex-specific death rates or survival rates for the most recent year or period. The survival rates are usually calculated for 5-year age groups and 5-year time intervals and are applied to the population distributed in 5-year age groups at one date to obtain the number of survivors 5 years older 5 years later.

$$ {}_5s_x^5 = {}_5P_x \cdot \frac{{}_5L_{x+5}}{{}_5L_x} \qquad (3) $$

Projections for single years of age or individual calendar years may be obtained by interpolation from the grouped data at quinquennial intervals. Once single ages have been derived at 5-year intervals, annual projections may be obtained by interpolation along single-age cohorts. If an electronic computer is available, however, the preferred procedure is to carry out the survival calculations directly in single ages for individual calendar years.

The various procedures of projecting mortality commonly involve a different and progressive set of survival rates for each succeeding 5-year period or other time unit over which the population is projected. Hence, each age cohort is carried forward, in effect, by a type of generation life table although generation life tables are not actually computed. Generation life tables which specifically reflect the effect of earlier influences on age cohorts have hardly been used in population projections. Generational effects represent the effects of health habits, preventive medicine, diseases and injuries, possibly genetic makeup, etc. upon the later chances of survival of the members of the cohort. These generational effects are difficult to measure, and it is not clear whether a reduction of mortality in the early life of a cohort increases or decreases its mortality at the older ages.[25] Spiegelman, Barnett, and others believe that many calendar-year influences affect most ages and may easily outweigh the generational influences.[26]

Projected death rates for a given country may be derived on the basis of a number of general procedures or assumptions. These are: (1) Maintaining the latest observed death rates, (2) extrapolating past trends in the country's own death rates in some fashion, (3) applying standard percentage decreases in death rates depending on the level of the death rate at each successive date, and (4) establishing target rates for a distant future date and securing rates for intermediate dates by some form of interpolation.

The first alternative would be applicable only where (a) mortality had reached a standstill and there were no signs of further progress or (b) the implications of other more realistic assumptions were being evaluated against this "base." The series of death rates may be extrapolated either graphically or by fitting an appropriate mathematical curve. The extrapolations under (2), (3), and (4) should all provide for improvement in mortality, with rare exceptions, and, if death rates are already low, the improvement should be at a decreasing rate. The extrapolations should be carried out independently for each age-sex group; and the same or different method of extrapolation may be used for different age-sex groups.

The risk of arriving at unreasonably low levels of mortality in the projection period when direct extrapolation is employed suggests that a limit should be set to the improvement assumed to occur. Accordingly, after a given future date, the rates at every age may be assumed not to change any farther. The target rates set to avoid unreasonable levels of future mortality may be reached in different years for different age-sex groups. They may be derived in a number of different ways: (1) Use of the rates already attained in some advanced geographic subdivision of the country; (2) use of the rates already attained in another, more advanced country, somewhat similar to the given country in certain socioeconomic features but having better public health organization and lower death rates;[27] (3) analysis of age-specific death rates in terms of components, such as principal causes of death, for which judgmental projections could more confidently be made; and (4) determination of the lower biological limit for mortality at each age on the basis of present knowledge, and of the date by which this limit will be attained.

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[25] Recent evidence on this question is given in: United Nations, "Factor Analysis of Sex-Age Specific Death Rates," *Population Bulletin of the United Nations*, Series N, No. 6, 1962, pp. 149–201.

[26] See Mortimer Spiegelman, *Introduction to Demography*, rev. ed., Cambridge, Mass., Harvard University Press, 1968, pp. 157–158; and H. A. R. Barnett, "Experiments in Mortality Graduation and Projection Using a Modification of Thiele's Formula," *Journal of the Institute of Actuaries* (England), 84(II,367): 212–229, 1958.

[27] See, for example, J. J. Paes Morais and A. Costa Leal, "A evolucão demográfica nacional e o desenvolvimento económico (National population trends and economic development), *Revista de economia* (Lisbon), 11(4):149–167, December 1958.

The third procedure for deriving target rates has been employed in a number of important studies in the United States.[28] It may be explained on the basis of the particular projection procedure described in Actuarial Study No. 62 of the U.S. Social Security Administration. Past trends in age-sex specific death rates were analyzed in terms of 10 cause-of-death classes, and medical research in progress was evaluated from the standpoint of the prospects of "breakthroughs" that would importantly affect the level of these rates. Low and high percentage reductions for each age-sex-cause specific death rate between 1960 and 2000 were then determined on the basis of the analysis of the historical trends in each rate and the assessment of the factors which could bring about further reduction (table 24–3). These percentage reductions were employed to derive age-sex-cause specific rates for the year 2000, which were then combined into general age-sex specific death rates for that year (table 24–4). The rates in the base year and in 2000 were then converted into 5-year survival rates by life-table construction methods; survival rates for intermediate years were derived by interpolation using an exponential curve.

If one cause of death plays a dominant role, it may suffice to project just this cause separately. In their mortality projections for India, Coale and Hoover considered malaria separately from other causes of death in view of the prevalence of that disease in India and of the prospects for rapid reduction in the disease through simple public health measures.[29]

Mortality models.—Mortality models, representing generalized schemes for projecting mortality applicable to a group of countries, are generally employed when satisfactory statistics are not available regarding the current level and trend of mortality for a country or group of countries. They are also used occasionally when such data are available. Mortality models may relate to the pattern by which current death rates are reduced over successive time units in the projection period, or to the way in which the terminal levels of mortality are determined, or to both; or they may establish specific levels of terminal mortality. (Further discussion of mortality models, relating to systems of model life tables, with applications to statistically underdeveloped countries for current or recent years, is given in ch. 25.)

The Princeton method (Coale) and the U.N. system of model life tables provide a basis for determining the projected changes in mortality at each observed or estimated level of mortality. The Census Bureau method (Campbell) provides a basis for determining projected changes and also sets specific terminal levels. Studies relating to the biological limit of mortality have been carried out at France's Institut national d'études démographiques (Bourgeois-Pichat). These studies are described briefly below.

An early generalized scheme of projecting mortality was the method developed by Coale at Princeton University in the 1940's.[30] His method was based on an historical analysis of age-specific death rates for populations of European origin. This analysis showed that the rate of decline of these death rates tended to vary directly with their level, without regard to country or year. He derived a set of curves for age-specific mortality rates (${}_5q_x$) by (1) separating the observed rates at each age into four segments on the basis of the level of the rates, (2) fitting straight lines by least squares to the three segments with the higher rates, (3) fitting an exponential curve to the segment with the lowest rates (the form of curve being chosen to prevent the rates from becoming negative when extrapolated), and (4) smoothing the junctures between segments.

The Princeton method was based wholly, or in large part, on pre-World-War-II mortality experience. In general, the decline of mortality has accelerated in the post-World-War-II period. Using postwar data, Campbell derived new constants for Coale's height-slope relationships and introduced certain "ultimate" levels of mortality at each age.[31] His principal equation is:

$$m_{x.t} = (m_{x.0} - m_{x.\infty})e^{-b_x t} + m_{x.\infty} \qquad (4)$$

where $m_{x.0}$ is a central death rate in the base year (last observed rate) at age x, $m_{x.t}$ is a central death rate t years after the base year at age x, $m_{x.\infty}$ is the ultimate central death rate at age x, b_x is a constant specific for age x, to be determined, and t represents the number of years for which the projection is desired. Like the Princeton study, this study found that, for each age group, higher death rates tend to decline more rapidly than lower death rates. It appeared from this new study, however, that the height-slope relationships observed before World War II have changed and that mortality has fallen much more rapidly since the end of the war than it did before the war. The study also followed the principle that the rate for any particular age should not fall below some minimum level, to be determined.

The two constants, b_x and $m_{x\cdot\infty}$, must be determined for each age x in order to apply equation (4). Then the death rate at age x for any year t years after the base year can be obtained by substituting the values for these constants and $m_{x\cdot 0}$ into the equation. For example, the formula for projecting the death rate for females 25 to 29 years old is as follows, given values of $m_\infty = 0.46$ per 1,000 population and $b = .162$:

$$m_t = (m_0 - .00046)e^{-.162t} + .00046$$

The death rate for any year t years after the base year is calculated by substituting values for m_0, the death rate in the base year, and t into the equation. If a country has a death rate of 8 per 1,000 population in the base year, 25 years later its death rate would be

$$m_{25} = (.008 - .00046)e^{-.162(25)} + .00046$$

$$= (.00754)(.01742) + .00046$$

$$= .0006$$

The constant b_x is a quantity representing the slope of a straight line which expresses absolute annual decline in mortality as a function of the level of mortality. The method

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[28] U.S. Bureau of the Census, *Forecasts of the Population of the United States, 1945–75*, by P. K. Whelpton *et al.*, 1947, pp. 8–13; U.S. Social Security Administration, Office of the Actuary, "Illustrative United States Population Projections," by T. N. E. Greville, *Actuarial Study No. 46*, May 1957, pp. 9–16; and idem, "United States Population Projections for OASDI Cost Estimates," by Francisco Bayo, *Actuarial Study No. 62*, December 1966, pp. 10–16. *Actuarial Study No. 46* was the basis of the projections of mortality incorporated in the population projections published by the U.S. Bureau of the Census in *Current Population Reports*, Series P–25, Nos. 286 and 381.

[29] Ansley J. Coale and Edgar M. Hoover, *Population Growth and Economic Development in Low-Income Countries*, Princeton, N.J., Princeton University Press, 1958, pp. 65–67 and 356–357.

[30] Notestein *et al.*, op. cit., pp. 183–189.

[31] U.S. Bureau of the Census, *International Population Reports*, Series P–91, No. 5, "A Method of Projecting Mortality Rates Based on Postwar International Experience," by Arthur A. Campbell, 1958, pp. 3–16.

Table 24–3.—Postulated Low Male Death Rates for the United States for the Year 2000 as Percent of the 1959–61 Rates, by Age and Cause-of-Death Group

Age (years)	Cause-of-death group[1]									
	I	II	III	IV	V	VI	VII	VIII	XI	X
Under 1	-	20	70	50	60	55	50	80	60	50
1 to 4	-	20	60	50	50	40	30	70	65	40
5 to 9	-	20	70	50	40	30	50	60	65	35
10 to 14	-	15	70	50	35	40	70	65	70	40
15 to 19	-	10	70	60	40	50	80	80	80	50
20 to 24	-	10	70	70	45	60	80	90	80	60
25 to 29	-	10	70	80	50	60	80	90	85	80
30 to 34	-	10	70	85	55	60	80	90	85	80
35 to 39	-	15	70	90	60	60	80	90	80	80
40 to 44	-	15	70	90	65	60	80	90	80	80
45 to 49	5	20	70	90	65	60	80	90	80	80
50 to 54	10	20	70	90	65	60	80	90	80	80
55 to 59	15	25	70	90	65	60	80	90	80	85
60 to 64	20	30	70	85	65	65	80	90	70	85
65 to 69	30	40	70	85	70	70	80	90	65	90
70 to 74	40	50	75	85	75	75	80	90	65	90
75 to 79	40	60	80	85	80	80	80	90	60	90
80 to 84	40	80	85	90	85	85	80	90	60	90
85 and over	50	90	90	90	90	90	80	90	50	90
Total, all ages[2]	21.6	31.0	74.0	86.6	74.4	69.7	51.4	79.3	74.7	82.4

– Represents zero.

[1] See source of table for explanation.

[2] Derived from the age-specific percentages by weighting on the basis of the 1960 census population.

Source: U.S. Social Security Administration, "United States Population Projections for OASDHI Cost Estimates," by Francisco Bayo, *Actuarial Study No. 62* December 1966, table 4.

Table 24–4.—Projected Death Rates for the United States for the Year 2000 According to Low and High Mortality Assumptions, Compared With Rates for 1959–61, by Age and Sex

Age (years)	Male					Female				
	1959-61	Low mortality, 2000	High mortality, 2000	Projected rates as percent of current rates		1959-61	Low mortality, 2000	High mortality, 2000	Projected rates as percent of current rates	
				Low [(2)÷(1)]x 100=	High [(3)÷(1)]x 100=				Low [(7)÷(6)]x 100=	High [(8)÷(6)]x 100=
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Under 1	30.40	16.56	23.48	54.5	77.2	23.19	12.67	17.93	54.6	77.3
1 to 4	1.15	0.61	0.88	53.0	76.5	0.96	0.49	0.73	51.0	76.0
5 to 9	0.56	0.31	0.43	55.4	76.8	0.41	0.23	0.32	56.1	78.0
10 to 14	0.56	0.34	0.45	60.7	80.4	0.32	0.19	0.26	59.4	81.3
15 to 19	1.28	0.93	1.11	72.7	86.7	0.54	0.35	0.44	64.8	81.5
20 to 24	1.81	1.34	1.57	74.0	86.7	0.70	0.46	0.58	65.7	82.9
25 to 29	1.71	1.32	1.51	77.2	88.3	0.88	0.60	0.74	68.2	84.1
30 to 34	2.01	1.49	1.75	74.1	87.1	1.23	0.85	1.04	69.1	84.6
35 to 39	2.85	2.00	2.42	70.2	84.9	1.79	1.21	1.50	67.6	83.8
40 to 44	4.59	3.22	3.91	70.2	85.2	2.76	1.81	2.28	65.6	82.6
45 to 49	7.48	5.18	6.33	69.3	84.6	4.20	2.70	3.45	64.3	82.1
50 to 54	12.31	8.44	10.38	68.6	84.3	6.39	4.01	5.20	62.8	81.4
55 to 59	18.58	12.79	15.68	68.8	84.4	9.31	5.98	7.64	64.2	82.1
60 to 64	27.74	18.91	23.33	68.2	84.1	14.58	9.58	12.08	65.7	82.9
65 to 69	40.88	29.33	35.10	71.7	85.9	22.44	15.33	18.88	68.3	84.1
70 to 74	58.19	44.22	51.21	76.0	88.0	36.26	25.89	31.07	71.4	85.7
75 to 79	84.98	68.07	76.53	80.1	90.1	60.08	47.02	53.55	78.3	89.1
80 to 84	132.23	111.81	122.02	84.6	92.3	104.23	86.41	95.32	82.9	91.5
85 and over	228.41	202.42	215.42	88.6	94.3	201.07	176.63	188.85	87.8	93.9
Total, all ages[1]	10.90	8.01	9.45	73.5	86.7	8.01	5.84	6.93	72.9	86.5

[1] Derived from the age-specific rates and percentages by weighting on the basis of the 1960 population.

Source: U.S. Social Security Administration, "United States Population Projections for OASDHI Cost Estimates," by Francisco Bayo, *Actuarial Study No. 62*, December 1966, table 5.

of deriving b_x involves first setting the level of m_∞ independently for each age. Then a value of b is determined for each observation (each country) from the equation,

$$b=\frac{m_t'}{m_t-m_\infty} \tag{5}$$

which is derived from equation (4). The value m_t' is the first derivative of m_t and represents the average annual decline for any death rate (m_t). The values of m_t and m_t' correspond, respectively, to the "heights" and "slopes" described in the preceding section. The values of b determined for the various countries at a particular age were averaged in order to obtain a single value to represent the general trend of the height-slope relationship at that age. These values of b were further adjusted to remove certain irregularities in the resulting trends in age-specific death rates.

The hypothetical low death rates, $m_{x.\infty}$, chosen do not greatly affect the projections of population for most age groups as long as the death rates assumed are below present levels and reasonable. Campbell derived the low death rates by (1) compiling a set of lowest observed age-specific death rates, (2) smoothing the observed lows graphically, (3) calculating maximum possible percentage reductions below the smoothed observed lows (ranging up to 50 percent for ages 20–24 years), and (4) reducing the smoothed observed lows by these percentages to obtain a set of hypothetical lows. Such mortality rates are intended only for use in making population projections. They are not intended to yield independently valid projections of future mortality rates.

The formulas are of doubtful utility in extrapolating death rates in countries whose postwar mortality experience has diverged widely from the average international trend. Similarly, they are not applicable to countries having mortality rates much higher than any of those used to estimate the constants of the projection formulas. The formulas may become obsolete as medical progress leads to improved mortality beyond the limits of the minimum mortality rates used in the projection formula.

Projections of mortality could also be based on the research findings at France's Institut national d'études démographiques regarding the separate trends of deaths from endogenous and exogenous causes and the biological "limit" of the death rate at each age.[32] As noted in chapter 14, the biological "limit" of the death rate for a given country is arrived at by separating out the exogenous causes of death from the total death rate at each age and considering the possibilities for further reduction in the endogenous death rates in the light of prospective medical developments in the particular country and of actual past developments in the most advanced countries. The "ultimate" level is still a function of the state of present knowledge and would have to be reexamined from time to time.

Without specifying either height-slope relationships or ultimate levels of mortality, the United Nations has developed a set of model life tables for projecting mortality.[33] They are based on analysis of 158 life tables representing the experience in the first half of the 20th century of 50 countries. The calculation of the model tables rests on the principles that the schedule of age-specific mortality rates is fairly well defined if the expectation of life at birth is known, and that expectation of life tends to increase by a fairly uniform annual amount until a moderately high level of life expectancy is reached.

The model tables were designed on the assumption that an annual gain of 0.5 year in expectation of life at birth will occur whenever the expectation is less than 55 years. At older ages, the gain increases, then declines. Twenty-four model tables (males and females for each model) are presented, reflecting differences of 2.5 years in expectation of life at birth (up to 55 years) over each 5-year time period and covering a time span of 115 years. The expectation of life for both sexes combined ranges from 20 to 73.9 years. Once a particular model table is selected to represent the current level of mortality or once the current level is established, the tables to be used for future mortality allowances are selected in rank order from the set of model tables. (See illustration below for Costa Rica in table 24–7.) To use the system of model life tables, the assumptions with respect to mortality have to be expressed in terms of $\mathring{e}_0$ for both sexes combined. This $\mathring{e}_0$ identifies a particular model life table which describes a whole age-pattern of mortality conditions.

Another system of model life tables, the Coale-Demeny model life tables, distinguishes regional variations in mortality patterns; four sets of life tables are given, with expectation values of 20.0 to 77.5 years, at intervals of 2.5 years.[34] The selection of tables was not designed to provide a progression of values directly applicable to projections, as were the U.N. tables. Once some assumptions regarding the improvement in mortality in a country have been developed, however, the Coale-Demeny model tables can effectively be employed to implement the assumptions. The tables are described more fully in chapter 25.

These systems of model tables may be used to project the mortality of countries for which only limited data on mortality are available. They may also be used to project mortality in developed countries under a unified system of projections. The use of a common system of mortality projections should add to the international comparability of the projections even though the procedure may be less refined than is possible for some countries.

Projections of Fertility.—We may distinguish three types of methods of projecting fertility as part of a cohort-component method of projecting population, namely, the period-fertility method, the cohort-fertility method, and the marriage-parity-interval progression method. Other methods of projecting fertility may be viewed as elaborations or combinations of these basic methods. In brief, the period-fertility method examines the trend of age-specific birth rates (or the corresponding age-adjusted summary measures of fertility) over past years for the same age groups. The cohort-fertility method examines the trend of fertility for separate birth cohorts or marriage cohorts of women, usually in terms of age-specific or duration-specific birth rates and cumulative and completed fertility rates for these cohorts. In the marriage-parity-interval progression method, probabilities of marriage and of birth by parity of women are employed to determine sequentially the number of births of various orders and the number of women who are at risk of giving birth to a child of a given order. Let us consider each of these in some detail.

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[32] John V. Grauman. op. cit., p. 571; Jean Bourgeois-Pichat, "Essai sur la mortalité 'biologique' de l'homme" (Essay on the "biological" mortality of man), *Population* (Paris), 7(3):381–394, July–Sept. 1952.

[33] United Nations, *Age and Sex Patterns of Mortality: Model Life Tables for Underdeveloped Countries*, Series A, Population Studies, No. 22, 1955; and idem, *Methods for Population Projections by Sex and Age*, Series A, Population Studies, No. 25, Manual III, Methods of Estimating Population, 1956.

[34] Ansley J. Coale and Paul Demeny, *Regional Model Life Tables and Stable Populations*, Princeton, N.J., Princeton University Press, 1966.

Period-fertility method.—In the period-fertility method, or the **age-specific birth rate method,** assumptions concerning future fertility are stated in terms of calendar-year or period age-specific birth rates, period sex-age adjusted birth rates, period total fertility rates, or period gross reproduction rates. The prototype procedure consists essentially of (1) calculating and analyzing a time series of birth rates for each (5-year) age group of woman; (2) holding the most recent rates constant over the projection period or projecting the rates on the basis of various assumptions and techniques to some future year; and then (3) applying the projected schedule of rates to the projected female population by 5-year age groups for a given future year to determine the corresponding number of births. The characteristic feature of the method is that the trend analysis is in terms of rates for a given age group. If the calculations are done manually, it is most convenient (1) to obtain the projected rates for the end of each quinquennium, (2) multiply the rates cumulatively by the number of women by age previously calculated to have survived to the end of the quinquennium, (3) average the births for the first and last years of each quinquennium, and (4) multiply by five (to secure births for a 5-year period).

This procedure may be abbreviated, with little change in the results, by projecting the period total fertility rate or the period gross reproduction rate instead of the schedule of age-specific birth rates. Applying any single reasonable set of age-specific rates (e.g., the rates for the current year) to the future numbers of women of childbearing age, with an adjustment to the projected total fertility rate (or gross reproduction rate), produces very nearly the same number of births as applying a projected schedule of age-specific birth rates. Variations in the pattern of age-specific birth rates tend to have little effect on the corresponding numbers of births, given the overall reproduction rate, so that the total fertility rate (or the gross reproduction rate) is a useful substitute for making projections of births by the age-specific birth rate method. This variation permits the application of the period-fertility method to areas where age-specific birth rates are lacking and where only the total number of births is known. The initial age-specific birth rates and total fertility rate can be estimated by the indirect method from (1) the total number of births, (2) the female population of childbearing age, and (3) an available set of age-specific birth rates for a similar area (ch. 16).

Among the several variations we have mentioned so far, we will illustrate first the use of the total fertility rate to project births, given current age-specific birth rates. Let us consider an example using the total fertility rate to project births for Costa Rica from 1965 to 1985 (table 24–5, **Method B**). We employ for this purpose the basic data and some of the assumptions of an official Costa Rican study, including the estimates of the population by age and sex and the recorded age-specific birth rates for 1965.[35] First, the total fertility rate is projected on some basis. In the present case, following the procedure of the official study, we made three assumptions regarding the future course of fertility, representing high, medium, and low alternatives. The high series assumes a continuation of the total fertility rate of 1965, the medium series a decline in the rate of 5 percent each 5 years, and the low series a decline in the rate of 10 percent each 5 years (table 24–6).

First, the current schedule of age-specific birth rates is assumed initially for all future dates and series. Next, these assumed rates are applied to the projected female population of childbearing age in each year (see below for method of derivation) to obtain the "expected" number of total births for that year (for all series). For example, under all assumptions the expected number of births in 1970 is derived by taking the cumulative product of the age-specific birth rates of 1965 and the projected female population of childbearing age in 1970 (table 24–5). This product is 75,344. Next, this number is multiplied by the ratio of the projected total fertility rate (*TFR*) in 1970 for a particular series to the total fertility rate for 1965, corresponding to the percent change in the rate for that series for 1965–70. For the medium series, for example, this ratio is .95 and the projected number of births in 1970 is 75,344 × .95, or 71,577. The projected number of births for 1965–70 is obtained by inflating by 5 (for 5 years) the average number of births for the period [$\frac{5}{2}$(62,821 + 71,577) = 335,995]. The projected number of female births is then derived by applying as assumed proportion female among births; e.g.,

$$335{,}995 \times .49 = 164{,}638$$

Similarly, to derive the projected number of births in 1975, under the medium series the expected number of births in 1975 is adjusted by the ratio of the projected *TFR* in 1975 under the medium series to the current *TFR* (this is, .9025). Note that, after 15 years of projecting births, it is necessary to begin carrying forward to older ages the female births which were projected in the first future 5-year period, so as to derive the female population of reproductive age; for example, the births of 1965–70 will become 15 to 19 years of age in 1985.

The calculations for the high and low series of births are presented in table 24–6. Since the high series assumes no change in the *TFR*, it corresponds to the expected numbers of births computed in table 24–5, the adjustment factors being 1.00 in each case. The low series of births in 1970 (67,810) was derived by adjusting the expected number of births in 1970 (75,344) by the ratio of the low series *TFR* for 1970 (5,886.5) to the *TFR* for 1965 (6,540.5)—.90; the low series of births in 1975 (75,088) was derived by adjusting the expected number of births in 1975 (92,701) by the ratio of the low series *TFR* for 1975 (5,297.9) to the *TFR* for 1965 (6,540.5)—.81; etc.

Use of the total fertility rate in this way is equivalent precisely to assuming that the age-specific birth rates change uniformly by age by the same percentage as the total fertility rate (table 24–5, **Method A**). Even if a different pattern of change in fertility by age is expected, the summary procedure is acceptable because of the negligible effect of variations in the age pattern of fertility on the number of births, once the total fertility rate is fixed. It may be recognized that the procedure of using the total fertility rate to project the number of births, just described, involves the same logic as the calculation of this rate by the indirect method, albeit the order of calculation is different. In the former case, we are given the population by sex and age, a standard set of assumed age-specific birth rates, and the total fertility rate, and we are asked to calculate the corresponding number of births. In the latter case, we are given the population by sex and age, a standard set of assumed age-specific birth rates, and the total number of births, and we are asked to calculate the corresponding total fertility rate. The procedure and logic with gross reproduction rates are essentially the same; there is no advantage in the use of this rate and

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[35] Costa Rica, Dirección general de estadística y censos, Proyección de la problación de Costa Rica por sexo y grupos de edad, 1965–90" (Projections of the population of Costa Rica by sex and age, 1965–90), by Ricardo Jiménez J. *et al.*, Serie Demográfica No. 5, *Revista de estudios y estadísticas*, San José, No. 8, October 1967.

Table 24–5.—Calculation of the Projected Medium Number of Female Births in Costa Rica by the Period-Fertility Method, for 1965 to 1985

[Methods A, B, and C represent three variations in the application of the period-fertility method]

Age of mother (years)	Age-specific birth rates (f_a)					Population (p_a)[2]					Population weights (w_a)
	1965[1]	1970	1975	1980	1985	1965	1970	1975	1980	1985	
15 to 19	110.9	105.4	100.1	95.1	90.4	72,385	92,466	116,881	142,217	157,262	1
20 to 24	301.9	286.8	272.5	258.9	245.9	58,115	71,914	92,022	116,472	141,847	7
25 to 29	319.6	303.6	288.4	274.0	260.3	48,275	57,650	71,483	91,617	116,076	7
30 to 34	258.1	245.2	232.9	221.3	210.2	42,325	47,836	57,241	71,090	91,214	6
35 to 39	212.4	201.8	191.7	182.1	173.0	36,875	41,872	47,420	56,835	70,671	4
40 to 44	89.3	84.8	80.6	76.5	72.7	29,815	36,381	41,395	46,960	56,352	1
45 to 49	15.9	15.1	14.3	13.6	12.9	25,200	29,260	35,781	40,786	46,340	-
Total fertility rate = $5 \Sigma f_a$	6,540.5	6,213.5	5,902.8	5,607.7	5,327.3						

	Births (B)				
	1965	1970	1975	1980	1985
Method A:					
1. Expected births, year y = $\Sigma f_a^y p_a^y$	62,821	71,579	83,661	99,011	115,405
2. Expected female births, 5 year period[3] = $[(B^y + B^{y+5}) \div 2] \times 5 \times .49$	164,640	190,169	223,773	262,660	
Method B:					
3. Expected births, year y = $\Sigma f_a^{65} p_a^y$	62,821	75,344	92,701	115,478	141,684
4. Projected medium births = (3) x $\frac{TFR^y}{TFR^{65}}$	62,821	71,577	83,653	99,009	115,403
5. Projected medium female births, 5 year period[3] = $[(B^y + B^{y+5}) \div 2] \times 5 \times .49$	164,638	190,169	223,773	262,655	
Method C:					
6. Weighted population = $\Sigma W_a p_a^y$	1,248,380	1,490,299	1,835,937	2,299,680	2,849,043
7. Sex-age adjusted birth rate, year y = s.a.a.b.r.$^{y-5}$ x .95	.5032	.4780	.4541	.4314	.4098
8. Projected medium births = weighted pop. x s.a.a.b.r. = (6) x (7)	62,818	71,236	83,370	99,208	116,754
9. Projected medium female births, 5 year period[3] = $[(B^y + B^{y+5}) \div 2] \times 5 \times .49$	164,216	189,392	223,658	264,553	

– Represents zero.

[1] Source: Costa Rica, Dirección general de estadística y censos, "Proyección de la población de Costa Rica por sexo y grupos de edad, 1965–90" (Projections of the population of Costa Rica by sex and age 1965–90), by Ricardo Jiménez J. *et al.*, Serie Demográfica No. 5, *Revista de estudios y estadísticas*, San José, No. 8, October 1967, table 34.

[2] See table 24–7.

[3] These births relate to the 5-year period from July 1 of initial year to June 30 of terminal year.

either measure allows for a change in the sex ratio of births with equal convenience.

The medium series of births, derived as described above, was employed in completing a set of projections of the female population of Costa Rica by 5-year age groups at 5-year time intervals to 1985 (table 24–7). For this purpose, we have adopted the current population estimates given in the Costa Rican report cited above.[38] The base population in 1965 (derived from the census of 1963) was adjusted for underenumeration of children under 10 years old and for age heaping in the range 10 years old and over. As in that report, we have assumed that there would be no immigration and that mortality would show a moderate gradual improvement after 1965. The projected survival rates were based on the observed death rates for 1963; they followed the assumption that expectation of life at birth would increase from 1.5 to 2.5 years over each 5-year time period, corresponding to the model life tables in U.N. Manual III.[37] The observed rates in 1963 corresponded most closely, on the average, to the rates in U.N. model life table 90 (or $\mathring{e}_0 = 65.8$). Therefore, for projection periods 1965–70, 1970–75, 1975–80, and 1980–85, we used model tables 95, 100, 105, and 110, corresponding to life expectation values of 68.2, 70.2, 71.7, and 73.0 years, respectively.

Five-year survival rates for each 5-year time period corresponding to each required mortality level were selected from the model tables and applied to the female population. The 1965–70 factors were applied to the 1965 population, by sex, to derive the projected population 5 years old and over in 1970, then the 1970–75 factors were applied to this population to derive the projected population 10 and over in 1975, etc. The projected births were developed on the basis of the projections of female population of childbearing age, as described earlier (Method B, medium series, in table 24–5). The births in 1965–

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[38] Ibid, p. 64.

[37] United Nations, *Methods for Population Projections by Sex and Age*, table V.

Table 24-6.—Calculation of Alternative Projections of Female Births in Costa Rica by the Period-Fertility Method, for 1965 to 1985

Series	1965	1970	1975	1980	1985
HIGH SERIES					
1. Total fertility rate, year y = 1.00 TFR^{y-5}	6,540.5	6,540.5	6,540.5	6,540.5	6,540.5
2. Expected births = $\Sigma F_a^{65} p_a^y$	62,821	75,344	92,701	115,478	141,684
3. Projected female births, 5-year period[1]	169,252	205,855	255,019	315,023	
MEDIUM SERIES					
4. Total fertility rate, year y = .95 TFR^{y-5}	6,540.5	6,213.5	5,902.8	5,607.7	5,327.3
5. Projected births = (2) x $\frac{(4)}{(1)}$	62,821	71,577	83,663	99,009	115,403
6. Projected female births, 5-year period[1]	164,638	190,169	223,773	262,655	
LOW SERIES					
7. Total fertility rate, year y = .90 TFR^{y-5}	6,540.5	5,886.5	5,297.9	4,768.1	4,291.3
8. Projected births = (2) x $\frac{(7)}{(1)}$	62,821	67,810	75,088	84,185	92,961
9. Projected female births, 5-year period[1].......	160,023	175,050	195,109	217,004	

[1] $[(B^y + B^{y+5}) \div 2] \times 5 \times 49$. These births relate to the 5-year period from July 1 of initial year to June 30 of terminal year.

70 were then carried forward to ages 0–4 in 1970 by use of the appropriate survival rate, the survivors 0–4 in 1970 were carried forward to ages 5–9 in 1975, etc.

A still simpler procedure for projecting births which is applicable when only total births and an age-sex distribution are available employs the U.N. sex-age adjusted birth rate (ch. 16). In this procedure we do not have to assume any particular pattern of age-specific rates. We have applied the procedure in table 24-5 (**Method** C) to Costa Rica, using the same general assumptions as before but without making use of the available age-specific birth rates. This procedure represents still another application of the logic of indirect standardization. Use of the sex-age adjusted birth rate was recommended by the United Nations as a simple means of preparing comparable projections for many countries.[38] It may be recalled that the U.N. sex-age adjusted birth rate is calculated by dividing the number of births by the cumulative product of the midperiod female population and a standard set of weights, and multiplying by 1,000. The standard set of weights is roughly proportional to the typical relative fertility rates of the various age groups and was chosen so that the resulting adjusted rate would be of the same order of magnitude as the crude birth rate. The U.N. rate represents a simple device for eliminating the effects of changes in sex-age structure in the measurement of the fertility trend and the estimation of future births.

For purposes of the population projections for Costa Rica, we begin by determining the U.N. sex-age adjusted birth rate for a current year (50.32). We then project the rate on the same assumptions as we projected the total fertility rate. For example, the sex-age adjusted birth rate under the medium assumption in 1970 is .95 × 50.32, or 47.80. We next calculate the weighted aggregate of women of childbearing age in each projection year and multiply the projected rate by the weighted aggregate:

$$B = s.a.a.b.r. \times W_a p_a^f \qquad (6)$$

For the medium series in 1970, we have:

$$B = .0478 \times 1{,}490{,}299$$

$$B = 71{,}236$$

It may be observed that in the present case the differences among the projections of births derived on the basis of the total fertility rate and the U.N. sex-age adjusted birth rate are very small for all years (table 24-5).

Some of the methods of extrapolating fertility rates parallel those of extrapolating mortality rates. Straight lines or curves may be fitted to determine the trend of the rates in the past, a rate of change may be assumed for each future quinquennium, a target schedule of rates may be assumed for the end of the projection period (or beyond) and intermediate values calculated by interpolation, and so on. Knowledge from a wide variety of sources can be brought to bear in making these assumptions. These include the trends in other countries, fertility differentials (e.g., urban-rural, geographic, ethnic) within the country in question, current practices and attitudes about family limitation as obtained from sample surveys or clinic records, national programs and plans in the field of family limitation, and information or theory concerning the relationship between fertility, on the one hand, and marriage patterns, family systems, sexual practices, infant mortality, survival to childbearing age, desired and expected numbers of children, employment of women outside the home, and economic conditions, on the other hand. As in the case of mortality, studies at the Institut national d'études démographiques in Paris are helping to provide information about the biological limits on fertility.[39] Henry has developed a mathe-

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[38] United Nations, *Methods for Population Projections by Sex and Age*, pp. 41–50.

[39] Louis Henry, "Fécondité et famille" (Fertility and family, *Population*, 12(3):413–444, July–September 1957.

Table 24-7.—Calculation of Projections of the Female Population of Costa Rica, by Age, According to the Medium Fertility Assumption, for 1970 to 1985

[Projections assume no net migration. Heavy lines identify a 5-year age cohort]

Age (years)	Estimated population, July 1, 1965[1] (1)	Survival rate, 1965-70[2] (2)	Projected population, July 1, 1970 (1) x (2)= (3)	Survival rate, 1970-75[2] (4)	Projected population, July 1, 1975 (3) x (4)= (5)	Survival rate, 1975-80[2] (6)	Projected population July 1, 1980 (5) x (6)= (7)	Survival rate, 1980-85[2] (8)	Projected population, July 1, 1985 (7) x (8)= (9)
All ages[3]	742,080	(X)	884,782	(X)	1,053,262	(X)	1,254,427	(X)	1,492,527
Births[4]	164,638	.9660	190,169	.9744	223,773	.9801	262,655	.9838	(X)
Under 5	144,520	.9892	159,040	.9925	185,301	.9948	219,320	.9963	258,400
5 to 9	117,715	.9962	142,959	.9972	157,847	.9981	184,337	.9986	218,509
10 to 14	92,875	.9956	117,268	.9967	142,559	.9976	157,547	.9982	184,079
15 to 19	72,385	.9935	92,466	.9952	116,881	.9965	142,217	.9974	157,263
20 to 24	58,115	.9920	71,914	.9940	92,022	.9956	116,472	.9966	141,847
25 to 29	48,275	.9909	57,650	.9929	71,483	.9945	91,617	.9956	116,076
30 to 34	42,325	.9893	47,836	.9913	57,241	.9929	71,090	.9941	91,214
35 to 39	36,875	.9866	41,872	.9886	47,420	.9903	56,835	.9915	70,671
40 to 44	29,815	.9814	36,381	.9835	41,395	.9853	46,960	.9868	56,352
45 to 49	25,200	.9731	29,260	.9754	35,781	.9775	40,786	.9792	46,340
50 to 54	21,275	.9609	24,522	.9637	28,540	.9661	34,976	.9680	39,938
55 to 59	16,065	.9402	20,443	.9437	23,632	.9466	27,572	.9491	33,857
60 to 64	12,520	.9036	15,104	.9083	19,292	.9122	22,370	.9161	26,169
65 to 69	9,205	.8429	11,313	.8490	13,719	.8549	17,598	.8609	20,493
70 to 74	6,190	.7525	7,759	.7602	9,605	.7677	11,728	.7764	15,150
75 to 79	4,085	.6323	4,658	.6410	5,898	.6493	7,374	.6592	9,106
80 and over	4,640	.3781	[5]4,337	.3828	[5]4,646	.3869	[5]5,628	.3913	[5]7,063

X Not applicable.

[1] Source: Costa Rica. Dirección general de estadística y censos, "Proyección de la población de Costa Rica por sexo y grupos de edad, 1965–1990" (Projections of the population of Costa Rica by sex and age, 1965–1990), by Ricardo Jiménez J. *et al.*, Serie Demográfica No. 5, *Revista de estudios y estadísticas*, San José, No. 8, October 1967, table 34.

[2] Selected from table V of: United Nations, *Methods for Population Projections by Sex and Age*, Series A. Population Studies, No. 25, 1956. See text for explanation.

[3] Total excludes births.

[4] See table 24–6, medium series.

[5] Derived from populations and survival rates on same and previous lines: $[(p^{f}_{75-79} \times s_{75-79}) + (p_{80+} \times s_{80+})]$.

matical model for the legitimate fertility of couples not practicing any form of birth control which takes account of a number of biological factors as well as of the duration of their marriages.

The method of projection of age-specific fertility rates developed by Coale and his colleagues at Princeton University for the League of Nations was similar to their method of projecting mortality rates in that the trend was determined by the height of the rate in the base period. "The fertility rate of each age group was projected on rectangular hyperbolas whose heights were determined by rates of the base periods, in general taken subsequent to 1935, and whose initial slopes, taken as of 1930, came from height-slope relations characterizing European experience in the 'twenties' and 'thirties.' "[40]

In its use of the sex-age adjusted birth rate (*s.a.a.b.r.*), the United Nations has usually formulated fairly simple arithmetic assumptions about future trends. Underlying the simple formulations, however, was usually a good deal of analysis and theory. In the projections published in 1966, for example, a considerable theoretical analysis led to a general assumption of a continuous but irregular decline of the *s.a.a.b.r.* for each region over a 30-year period to one-half of its initial level, for the high fertility countries.[41] Alternative dates of onset were set for each region; the high fertility assumption represents a late date and the low fertility assumption, an early date. (See discussion of "United Nations Projections of 1966" below.)

Cohort-fertility method.—The period-fertility method is very simple to apply operationally, but it does not always yield reasonable levels of implied family size. Furthermore, there is no logical basis for projecting the trend of annual fertility and the levels assumed for various dates in the projection period are extremely arbitrary. The cohort-fertility approach tries to overcome these weaknesses of the period-fertility approach. The variation of the cohort-fertility method described here employs data on the fertility history of birth cohorts of women, as they progress through the childbearing ages. As may be recalled from chapter 16, cohort fertility data represent the cumulative fertility of specific birth cohorts of women to each successive age. It may be noted that this variation of the method, like the period method, involves only the variable of age.

In the cohort-fertility approach, the fertility assumptions are directly formulated in terms of the completed fertility of real cohorts of women, so that unreasonable or unlikely assumptions concerning completed family size may be avoided. In fact, projections of births derived by other procedures should be evaluated, in part, in terms of the implied completed family size. The cohort-fertility approach makes possible the use of additional information and relationships, such as information on the expressed expectations of women regarding completed family size that have been obtained in national or local sample surveys, and historical evidence regarding the relation of cumulative fertility or mean age of childbearing to completed fertility size, etc.

The cohort-fertility method may be applied in different ways. We describe the variation employed by the U.S. Census

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[40] Notestein *et al.*, op. cit., p. 189.

[41] United Nations, *World Population Prospects as Assessed in 1963*, pp. 45–46.

Bureau in its 1967 projections. The steps are:[42]

1. Selecting "terminal" levels of completed fertility for the annual birth cohorts of women which will reach childbearing age in the future (table 24-8). Four alternatives, corresponding to the four series of population projections planned, were selected. They are as follows: Series A, 3,350; Series B, 3,100; Series C, 2,775; Series D, 2,450. In arriving at these figures, account was taken of "expectations" data from various national fertility surveys and of historical trends regarding the variations in completed family size.
2. Assigning age patterns, representing the distribution of births by age of mother over the childbearing span, to the terminal levels of completed fertility in step (1) (table 24-8). Four patterns corresponding to each of the four terminal levels of completed fertility were selected. They are based on the age patterns of fertility of various historical cohorts which had completed fertility rates similar to those set for the four series.
3. Developing assumptions on the completed fertility of each annual birth cohort of women which had already reached childbearing age by the base year of the projections, consistent with cumulative fertility to date for each cohort and in line with the assumed distribution by age and the assumed completed fertility rates for the cohorts which will reach childbearing age in future years determined in steps (1) and (2) (table 24-9). The completed fertility rates for these older cohorts would not agree with those for the younger cohorts in step (1) because of the fertility cumulated to date.
4. Calculating the cumulative fertility rates for each cohort to each age of childbearing, and the implied age-specific birth rates, in each future year (table 24-10).
5. Applying the age-specific rates in step (4) to projections of the female population of childbearing age to obtain the number of births for each year.

The cohort-fertility rates are first extended to the most recent year for which the total number of births is known and then tied in with the overall level of fertility estimated for that year. This is accomplished by projecting the available age-specific birth rates according to various assumptions to the current year, selecting that series which most closely yields the reported number, and then adjusting the rates to yield exactly the reported number of births (cf. indirect method of standardization, ch. 16). In the procedure followed by the U.S. Bureau of the Census, cumulative fertility data available from the National Center of Health Statistics to January 1, 1965, were projected to January 1, 1966, and were then forced to be in line with the estimated number of births for 1965. The cumulative rates for the various cohorts for January 1, 1966, were then extended to the end of the childbearing period on the basis of previously established assumptions regarding their completed fertility and the pattern of age-specific birth rates. Similar patterns were used to distribute the assumed completed fertility of new cohorts entering the childbearing ages after 1965 over the childbearing period.

In preparing these projections limited account was taken of information on the expectations regarding completed family size reported by representative national samples of married couples included in the Growth of American Families (GAF) Studies of 1955 and 1960 and in the University of Michigan

Table 24-8.—**Summary of Age-Specific Birth Rates Used in Distributing Terminal Completed Cohort Fertility Rates by Age, According to Four Projection Series, for the United States**

[Rates are based on the female population adjusted for net census undercounts. These rates apply exactly to cohorts born after July 1, 1954 and reaching age 14 after July 1, 1968]

Age of woman (years)	Series A	Series B	Series C	Series D
BIRTH RATES				
15 to 19[1]	87.4	77.0	64.5	51.8
20 to 24	233.7	203.6	168.0	131.8
25 to 29	180.9	167.9	150.8	133.8
30 to 34	102.5	103.1	101.6	100.4
35 to 39	50.7	53.0	54.3	55.9
40 to 44	14.0	14.6	15.0	15.4
45 to 49[2]	0.8	0.9	0.9	0.9
Completed fertility rate[3]	3,350.0	3,100.0	2,775.0	2,450.0
Median age of mother	25.3	25.8	26.4	27.2
PERCENT OF TOTAL				
15 to 19	13.0	12.4	11.6	10.6
20 to 24	34.9	32.8	30.3	26.9
25 to 29	27.0	27.1	27.2	27.3
30 to 34	15.3	16.6	18.3	20.5
35 to 39	7.6	8.5	9.8	11.4
40 to 44	2.1	2.4	2.7	3.1
45 to 49	0.1	0.1	0.2	0.2
Completed fertility rate	100.0	100.0	100.0	100.0

[1] Includes births to women under 15 years of age.
[2] Includes births to women 50 years old and over.
[3] Sum of age-specific birth rates over all childbearing ages for cohorts born after July 1, 1954 and reaching age 14 after July 1, 1968.

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 381, "Projections of the Population of the United States, by Age, Sex, and Color to 1990, With Extensions of Population by Age and Sex to 2015," December 18, 1967, table S.

Table 24-9.—**Estimated and Assumed Completed Fertility Rates, for 5-Year Birth Cohorts of Women, According to Four Projections Series, for the United States: Birth Years, 1900-05 to 1960-65**

[Average number of children born by end of childbearing period per 1,000 women. Rates below the heavy line are projections. Completed fertility rates for birth periods 1950-55 and later correspond approximately (1950-55) or exactly (1955-60 and later) to the "terminal" rates]

Birth period of women[1]	Age on July 1, 1965 (years)	Cumulative fertility rate to Jan. 1, 1966	Completed fertility rate			
			Series A	Series B	Series C	Series D
1900-1905	60 to 64	2,421	2,421	2,421	2,421	2,421
1905-1910	55 to 59	2,273	2,273	2,273	2,273	2,273
1910-1915	50 to 54	2,310	2,310	2,310	2,310	2,310
1915-1920	45 to 49	2,553	2,553	2,553	2,553	2,553
1920-1925	40 to 44	2,844	2,865	2,865	2,863	2,863
1925-1930	35 to 39	2,978	3,133	3,122	3,117	3,115
1930-1935	30 to 34	2,913	3,383	3,372	3,366	3,357
1935-1940	25 to 29	2,284	3,368	3,346	3,322	3,295
1940-1945	20 to 24	1,084	3,305	3,111	2,971	2,883
1945-1950	15 to 19	157	3,320	3,087	2,778	2,504
1950-1955	10 to 14	3	3,347	3,098	2,775	2,451
1955-1960	5 to 9	-	3,350	3,100	2,775	2,450
1960-1965	Under 5	-	3,350	3,100	2,775	2,450
1965 and later	(2)	-	3,350	3,100	2,775	2,450

– Represents zero.
[1] Period extends from July 1 of initial year to June 30 of terminal year.
[2] Born after July 1, 1965.

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 381, "Projections of the Population of the United States, by Age, Sex, and Color to 1990, With Extensions of Population by Age and Sex to 2015," December 18, 1967, table R.

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[42] U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 381, "Projections of the Population of the United States, by Age, Sex, and Color to 1990, With Extensions of Population by Age and Sex to 2015," by Jacob S. Siegel, December 1967, pp. 18-32 and appendix A.

Table 24-10.—Estimates and Projections of Cumulative and Completed Fertility Rates, by Birth Cohort of Women, According to All Series and Series C, for the United States: Birth Years, 1900-01 to 1939-40

[Rates represent cumulative live births per 1,000 women up to age indicated. Rates below heavy lines are based, in whole or part, on age-specific birth rates projected for years after 1966]

Birth year of mother	Up to age 20	Up to age 25	Up to age 30	Up to age 35	Up to age 40	Completed fertility rate	Median age of mother
	All series						
1900-1901	287	1,112	1,780	2,195	2,430	2,511	25.9
1901-1902	310	1,115	1,750	2,135	2,355	2,435	25.7
1902-1903	314	1,113	1,737	2,121	2,344	2,426	25.7
1903-1904	315	1,091	1,697	2,083	2,310	2,392	25.8
1904-1905	314	1,053	1,646	2,026	2,261	2,343	25.9
1905-1906	311	1,028	1,602	1,981	2,226	2,306	25.9
1906-1907	307	1,004	1,564	1,946	2,202	2,282	26.1
1907-1908	303	982	1,539	1,934	2,201	2,279	26.3
1908-1909	290	933	1,478	1,888	2,154	2,230	26.5
1909-1910	281	916	1,476	1,910	2,188	2,268	26.8
1910-1911	279	897	1,467	1,926	2,205	2,285	27.1
1911-1912	274	888	1,472	1,951	2,222	2,303	27.2
1912-1913	264	879	1,487	1,979	2,246	2,328	27.3
1913-1914	248	868	1,499	1,988	2,253	2,334	27.4
1914-1915	240	856	1,498	1,986	2,252	2,331	27.4
1915-1916	243	871	1,538	2,035	2,307	2,387	27.3
1916-1917	244	891	1,590	2,088	2,362	2,442	27.2
1917-1918	248	930	1,649	2,155	2,442	2,522	27.3
1918-1919	263	1,003	1,742	2,269	2,560	2,640	27.2
1919-1920	273	1,034	1,827	2,391	2,695	2,777	27.2
	Series C						
1920-1921	269	1,016	1,841	2,406	2,701	2,778	27.0
1921-1922	273	1,049	1,886	2,457	2,747	2,822	27.0
1922-1923	281	1,087	1,924	2,500	2,782	2,854	26.9
1923-1924	289	1,126	1,980	2,558	2,834	2,903	26.8
1924-1925	280	1,166	2,048	2,622	2,893	2,959	26.7
1925-1926	266	1,205	2,105	2,676	2,937	3,002	26.5
1926-1927	275	1,253	2,162	2,724	2,971	3,036	26.3
1927-1928	320	1,322	2,256	2,817	3,058	3,124	26.2
1928-1929	351	1,376	2,315	2,867	3,100	3,166	26.0
1929-1930	377	1,449	2,415	2,966	3,191	3,258	25.8
1930-1931	384	1,480	2,445	2,974	3,197	3,264	25.7
1931-1932	407	1,550	2,526	3,034	3,257	3,324	25.5
1932-1933	426	1,633	2,619	3,112	3,337	3,404	25.3
1933-1934	438	1,675	2,649	3,126	3,352	3,420	25.2
1934-1935	448	1,704	2,658	3,120	3,348	3,416	25.0
1935-1936	454	1,729	2,655	3,110	3,339	3,408	24.9
1936-1937	464	1,730	2,615	3,069	3,300	3,369	24.8
1937-1938	479	1,735	2,576	3,032	3,264	3,333	24.7
1938-1939	481	1,714	2,516	2,973	3,207	3,276	24.7
1939-1940	487	1,691	2,462	2,920	3,155	3,225	24.6

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 381, "Projections of the Population of the United States, by Age, Sex, and Color to 1990, With Extensions of Population by Age and Sex to 2015," Dec. 18, 1967, table A-1.

national sample surveys of 1962, 1963, and 1964.[43] (See the section on "Expected and Ideal Size of Family" in ch. 17.) The methods and results of these studies were rather similar. The terminal levels of completed fertility assumed for the B and C Series of fertility projections "straddled" the mean number of children expected by women in these surveys.

The cohort method of projecting fertility may be extended to take into account other variables in addition to age, particularly marital status. Like the general cohort method, this method employs cumulative fertility rates for birth cohorts of women and assumed levels of completed fertility. In this more elaborate method, however, the rates relate only to married women, and hence assumptions must be made about the proportion of women in each birth cohort who will have married by various later ages and about the fertility rates for ever-married women cumulated to these ages. The cumulative fertility experience of each birth cohort to date for ever-married women is taken into account, of course.

Applications of this method were made by Whelpton and his associates, who based their projections of completed fertility of ever-married women on the fertility expectations reported by married women in the 1955 and 1960 GAF Studies.[44] In their second study, they developed three series of population projections—high, medium, and low—based on different assumptions regarding the percent of women who will ever marry, the "average size of family" (i.e., completed fertility rate for ever-married women), and the distribution of birth rates by age of mother for ever-married women over the childbearing span. (The mortality assumptions were essentially the same as those used in the Census Bureau projections, except that the computations were carried out for 5-year age groups by 5-year time periods. Net immigration was assumed to be 300,000 per year, distributed by age and sex like the immigrant aliens in the period 1957 to 1962.) The specific steps followed in developing the three series of projections of births are as follows:

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[43] The former studies were carried out by the Scripps Foundation for Research in Population Problems, Miami University, and the Survey Research Center, University of Michigan, and the latter studies were carried out by the Population Studies Center and the Survey Research Center, University of Michigan. The methods and results of the 1955 and 1960 surveys are described in: Ronald Freedman, Pascal K. Whelpton, and Arthur A. Campbell, *Family Planning, Sterility, and Population Growth*, New York, McGraw Hill, 1959; and Pascal K. Whelpton, Arthur A. Campbell, and John E. Patterson, *Fertility and Family Planning in the United States*, Princeton, N.J., Princeton University Press, 1966. The design and results of the 1962-64 studies are described in: Ronald Freedman and Larry Bumpass, "Fertility Expectations in the United States: 1962-64," *Population Index*, 32(2):181-197, April 1966.

[44] Freedman, Whelpton, and Campbell, op. cit., chapter 11; and Whelpton, Campbell, and Patterson, op. cit., chapter 10.

1. Projections were made of the proportion of women who will have married by specified ages in groups of birth cohorts (tables 24-11 and 24-12). The three series imply corresponding changes in median age at marriage. For example, the medium series implies a small increase (less than 1 year) in the median age at marriage.

2. Next, projections were made of the cumulative fertility rates of ever-married women up to specified ages in groups of cohorts, including the final ages of fertility. The cumulative marital fertility rates for each cohort group were projected to the end of the childbearing ages on the basis of the average expectations regarding the size of completed families reported in the GAF Studies. The cumulative figures up to specified ages also had to be determined. For example, for cohorts entering the marriageable ages about 1980-85, 74.0 percent of the cumulative births for ever-married women would have occurred by age 30 in the medium series, as compared with 59.0 percent for the cohorts entering the marriageable ages in the early 1930's.

3. The cumulative fertility rates for ever-married women in groups of birth cohorts were then converted into rates for all women by multiplying the cumulative fertility rate for ever-married women in a given age group at a given date (item 2 above) by the proportion of women who have married by that age (item 1 above):

$$\frac{B_{cum}}{P^f} = \frac{P^f_{em}}{P^f} \times \frac{B_{cum}}{P^f_{em}} \qquad (7)$$

The "medium" size of completed family indicated by the married women in the GAF Study of 1960 was adjusted to represent all women and accepted as the medium assumption for completed family size in the Scripps Foundation projections (2,820). The high (3,395) and low (2,275) assumptions correspond to the highest and lowest completed fertility rates that have been reached or seem likely to be reached by cohorts born so far in this century (1930-35 and 1905-15, respectively).

4. The rise from one age group to another in the cumulative fertility rate of all women, for a given group of birth cohorts (item 3), was used to derive the number of births added per 1,000 women in a given initial age group during each 5-year interval.

5. The projections of births per 1,000 women in a given initial age group in a 5-year period (item 4) were then applied cumulatively to the female population by age at the beginning of the interval to obtain the number of births occurring to the women during the period.

Table 24-11.—**Estimated and Projected (Medium Series) Cumulative Marriage and Fertility Rates for Cohorts of Women Born in 1930 to 1935, by Successive Ages, for the United States**

[These cohorts reach 15 to 19 years of age in 1950 and 45 to 49 years of age in 1980. Percents and rates below the horizontal line are projections]

Age (years)	Cumulative percent ever married (1)	Number of births per 1,000 women ever married (2)	Number of births per 1,000 total women (1) x (2)= (3)
15-19....................	17.3	729	126
20-24....................	69.8	1,397	975
25-29....................	89.3	2,390	2,134
30-34....................	92.5	3,075	2,844
35-39....................	94.0	3,350	3,149
40-44....................	95.0	3,440	3,268
45-49....................	95.5	3,450	3,295

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 286, "Projections of the Population of the United States, by Age and Sex: 1964 to 1985, With Extensions to 2010," July 1964, table D-2.

Table 24-12.—**Estimated and Projected (Medium Series) Cumulative Marriage and Fertility Rates Up to Ages 45 to 49, for 5-year Birth Cohorts of Women, for the United States: Birth Years, 1900-05 to 1950-55**

[Percents and rates below the horizontal line are projections]

Birth period of woman[1]	Year in which cohorts reach—		Percent ever married	Births per 1,000 women ever married	Births per 1,000 total women (3) x (4)=
	Ages 15 to 19 (1)	Ages 45 to 49 (2)	(3)	(4)	(5)
1900-1905........	1920	1950	92.2	2,625	2,420
1905-1910........	1925	1955	92.4	2,458	2,271
1910-1915........	1930	1960	93.3	2,481	2,315
1915-1920........	1935	1965	95.0	2,700	2,565
1920-1925........	1940	1970	96.5	3,000	2,895
1925-1930........	1945	1975	96.0	3,300	3,168
1930-1935........	1950	1980	95.5	3,450	3,2[illegible]5
1935-1940........	1955	1985	95.0	3,300	3,135
1940-1945........	1960	1990	94.5	3,200	3,024
1945-1950........	1965	1995	94.5	3,100	2,930
1950-1955........	1970	2000	94.0	3,000	2,820
1955 or later....	1975 or later	2005 or later	94.0	3,000	2,820

[1] Period extends from July 1 of initial year to June 30 of terminal year.

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 286, "Projections of the Population of the United States, by Age and Sex: 1964 to 1985, With Extensions to 2010," July 1964, table D-1.

Another demographic variable which may be taken into account in the application of the cohort-fertility method is the order of birth of the child. Completed fertility rates for a given birth cohort and birth order would represent the number of births of a given order per 1,000 women or ever-married women at the end of childbearing. The available cohort fertility tables for the United States include order of birth as a variable, but not marital status.[45] It would be possible, however, to extend the cohort-fertility method to include both order of birth and marital status. The expectations data from the fertility surveys provide a basis for making assumptions regarding the fertility rates for first births, second births, etc., at the end of childbearing. This approach requires assumptions not only about the completed fertility of each cohort and the timing of their future births, but also about the future age at marriage, or percents ever-married by age, and order-specific marital fertility. These additional assumptions, like the basic ones required by the simpler variation, are subject to considerable uncertainty and may contribute to an increase in the "error" of the projections. On the other hand, the explicit introduction of the additional variables relating to marriage and order of birth assures reasonable implicit assumptions in these components of the overall fertility rates.

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[45] See, for example, U.S. National Center for Health Statistics, *Vital Statistics of the United States, 1966*, Vol. 1, *Natality*, 1968.

In spite of the apparently superior logic of the cohort-fertility approach to projections of births as compared with the period-fertility method, it has a number of weaknesses. First, there are serious difficulties in determining the future level of completed fertility of each cohort; yet, the results depend heavily on these assumptions. Expressed birth expectations may be unreliable because of changing circumstances, particularly for young women who have recently married and who have not begun childbearing. Making assumptions about the level of completed fertility is particularly hazardous for cohorts which have not yet married or even entered the childbearing ages, for whom expectations data are not available. (In only a few years women who are not currently married will be contributing a large share of births—about 50 percent in the fifth year of the projection period on the basis of U.S. data, for example.)

There are problems also in developing realistic assumptions regarding the timing pattern of the various cohorts—the other important determinant of the annual number of future births. (Changes in timing affect period rates even when the size of the completed family does not change.) The past may not be a good guide because of prospective changes in the socioeconomic milieu, and the survey data on birth expectations now available can tell us little or nothing about future annual changes in fertility, particularly after a few years of the projection period have passed.[46] Mathematical procedures for projecting the fertility of cohorts which have already started childbearing may be useful for these cohorts but cannot serve as a satisfactory basis of projecting the total fertility and timing pattern of cohorts which have not yet entered childbearing.[47] Accordingly, research has turned to an alternative method, the marriage-parity-interval progression method, which involves a greater disaggregation of the data and a more realistic structuring of the components.

Marriage-parity-interval progression method.—A number of sequential probability methods may be devised which take several fertility-related variables into account simultaneously. They employ fertility rates in the form of probabilities and essentially operate in attrition fashion, using as successive bases the progressively smaller numbers of women who have experienced each successive type of event. The particular sequential probability method described here, designated the marriage-parity-interval progression method, takes joint account of the variables of marriage, parity, and birth interval, as the name suggests. Single women are reduced in numbers by marriage, childless married women may become 1-parity women, 1-parity women may become 2-parity women, etc. The specific procedure employed in developing "high" projections of births for the United States from 1960 on by the marriage-parity-interval progression method, as devised by Wilson H. Grabill of the U.S. Bureau of the Census, is as follows:[48]

1. First marriage rates (i.e., first marriages at a given age per 1,000 women single at the next younger age) were computed by single years of age, primarily on the basis of the 1960 census data on the percent single among women (table 24-13). As suggested in chapter 19, such rates may be computed on the basis of the age-to-age changes in the percent single shown by the census, expressed as a percent of the figure at the earlier age. (Adjustments may then be made to obtain a smoother pattern of marriage rates at some ages.)

Table 24-13.—**Assumed (High Series) First Marriage Rates for the White Population of the United States, by Age**

[First marriages at age x per 1,000 women single at age $x-1$]

Age at last birthday (years)	First marriage rates	Age at last birthday (years)	First marriage rates
14	11	30	60
15	12	31	45
16	35	32	35
17	67	33	29
18	142	34	23
19	212		
20	239	35	18
21	255	36	17
22	250	37	16
23	235	38	15
		39	13
24	200		
25	170	40	11
26	140	41	16
27	120	42	8
28	100	43	7
29	80	44	7

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 286, "Projections of the Population of the United States, by Age and Sex: 1964 to 1985, With Extensions to 2010," July 1964, table E-1.

2. These age-specific first marriage rates (item 1 above), in combination with an initial distribution of single women by age and age-specific survival rates, were used to derive annual projections of first marriages of women of childbearing age, and of women who were still single, by age. The marriage rates and survival rates were first applied to the single population by age on the census date to obtain estimates of the number of women who married in the year after the census and the number still single at the end of the year. This process was repeated from year to year. (A single set or a variable set of first marriage rates could be used in future years.)

3. Next, parity-interval-specific birth rates were estimated. As may be recalled, a parity-interval-specific birth rate represents the probability that a woman of parity n at a given date will have a birth of order $n+1$ during the next year, specific by the interval since marriage or previous birth. For this purpose, it was necessary, in effect, to develop estimates of women by parity and interval since the birth of the previous child (interval since marriage for childless or zero-parity women) and of births by order and interval since the birth of the next lower order. In the calculation of the parity-interval-specific rates, extensive use was made of annual birth registration data by age and order

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[46] For a general criticism of expectations data as a basis for projections of births, see Norman B. Ryder and Charles F. Westoff, "The Trend of Expected Parity in the United States: 1955, 1960, and 1965," *Population Index* 33(2):153-168, April-June, 1967; and Jacob S. Siegel and Donald S. Akers, "Some Aspects of the Use of Birth Expectations Data from Sample Surveys for Population Projections," *Demography* 6(2):101-115, May 1969.

[47] Donald S. Akers, "Cohort Fertility vs. Parity Projection as Methods of Projecting Births, *Demography*, 2:414-428, 1965.

[48] U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 286, "Projections of the Population of the United States, by Age and Sex, 1964 to 1985, With Extensions to 2010," by Jacob S. Siegel, Meyer Zitter, and Donald S. Akers, July 1964, pp. 35-37 and 84-86.

of birth over a period of about 20 years compiled by the National Center for Health Statistics, and of sample survey data compiled by the Bureau of the Census that classified women by date of marriage and date of birth of each child and from which interval between births was inferred.[49] Intervals of 12 months were used in the distribution of women in each parity group, and parity groups up to the sixth (the terminal group being seventh and over) were considered separately. Two sets of birth rates for the second to sixth order were computed—an "initial" set which was assumed to apply only to the year after April 1, 1960, and a "terminal" set which was assumed to apply to certain later years (table 24-14).

4. The initial parity-interval-specific birth rates (item 3) were then applied to the female population by parity and birth interval in 1960 to secure projections of births by order and birth interval in the year after the 1960 census. The results were then used to obtain projections of the female population by parity and birth interval for the end of the first year, which became the basis for the application of the interpolated parity-interval-specific birth rates for the second year after April 1, 1960, and so on sequentially. If allowance has to be made for illegitimate births, first births may be increased by an appropriate percentage. Alternative series of birth projections could be based on higher or lower parity-interval-specific birth rates.

In the application of the marriage-parity-interval progression method described, no direct account was taken of the distribution of the women by age or year of marriage in estimating the births (except in the projection of first marriages). However, the concentration of births within a narrow spacing range provides some indirect control of age. In the absence of information on age, it is very difficult to convert the fertility rates used in the marriage-parity-interval progression method into completed fertility rates for birth cohorts. The method can be elaborated to incorporate the factor of age or duration of married life, but the necessary information is only infrequently available.

The application of the marriage-parity-interval progression method requires a considerable volume of data relating to the marriage and childspacing practices of women, based preferably on census or survey data on marriage histories and birth rosters for age cohorts of women. Even so, at best, only current rates can be directly derived from these data, and pro-

Table 24-14.—Assumed (High Series) Initial and Terminal Values for Parity-Specific Birth Rates of Children of First to Fifth Order, by Birth Interval, for the White Population of the United States

[Births of given order *n* during interval per 1,000 women of parity *n*—1 at start of interval]

Interval since first marriage of women or since birth date of previous child (months)	1st births per 1,000 0-parity women[1]	Initial values				Terminal values			
		2nd births per 1,000 1-parity women	3rd births per 1,000 2-parity women	4th births per 1,000 3-parity women	5th births per 1,000 4-parity women	2nd births per 1,000 1-parity women	3rd births per 1,000 2-parity women	4th births per 1,000 3-parity women	5th births per 1,000 4-parity women
0 to 11	332	39	28	23	20	36	25	21	20
12 to 23	409	357	221	201	180	335	198	183	172
24 to 35	317	351	215	188	170	323	191	168	155
36 to 47	234	302	184	147	133	261	158	125	114
48 to 59	179	262	142	108	99	214	119	88	79
60 to 71	153	199	108	59	55	150	89	42	35
72 to 83	118	159	85	50	48	117	69	35	30
84 to 95	85	125	68	41	41	92	54	28	25
96 to 107	62	108	56	36	36	75	44	24	22
108 to 119	43	87	46	30	31	61	36	20	19
120 to 131	39	63	21	22	22	44	13	10	9
132 to 143	30	49	18	14	14	38	11	7	6
144 to 155	23	43	16	10	10	34	10	5	4
156 to 167	17	44	16	8	8	27	10	4	3
168 to 179	13	42	15	6	5	22	9	3	2
180 to 191	13	31	11	3	3	18	7	1	1
192 to 203	11	20	6	-	-	13	4	-	-
204 to 215	8	14	-	-	-	8	-	-	-
216 to 227	7	10	-	-	-	4	-	-	-
228 to 239	5	5	-	-	-	3	-	-	-
240 to 251	6	2	-	-	-	2	-	-	-
252 to 263	4	1	-	-	-	1	-	-	-
264 to 275	3	-	-	-	-	-	-	-	-
276 to 287	2	-	-	-	-	-	-	-	-
288 to 299	1	-	-	-	-	-	-	-	-
300 and over	-	-	-	-	-	-	-	-	-

—Represents zero or rounds to zero.

[1] Initial and terminal values are the same.

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 286, "Projections of the Population of the United States, by Age and Sex: 1964 to 1985, With Extensions to 2010," July 1964, tables E-2 and E-3.

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[49] U.S. Bureau of the Census, *Current Population Reports*, Series P-20, No. 108, "Marriage, Fertility, and Childspacing," August 1959, by Wilson H. Grabill and Robert Parke, Jr., July 12, 1961.

jection of the rates to allow for possible future changes is still necessary. There may be few, if any, guides for doing this, as in the case of cohort fertility rates.

The marriage-parity-interval progression method may be most useful in making short-term projections of births since changes in marriage and childspacing patterns would be expected to change less in the short term than in the long term. In the long term it would seem useful to "control" the changes in fertility to some predetermined level of cohort-completed fertility, possibly by merging the two methods after several years and then shifting entirely over to the cohort method in the long term.[50] The refinement of the marriage-parity-interval progression method of projecting fertility may serve as the fertility component of a complex demographic model based on aggregated data using macrosimulation techniques (ch. 22, "Demographic Models").

Projections of Net Immigration.—For many countries international migration has long been of negligible magnitude, and for others it has dwindled away to a trickle as compared to the heavy flows of the past. The passing of the frontiers of settlement and the enactment of very rigid national laws with respect to either immigration or emigration, or both, have contributed to this reduction of migration flows in relation to the corresponding national population totals, and there is little likelihood of a resumption of heavy flows. The volume of net immigration will often be too small, therefore, to justify separate treatment of this component in population projections. Frequently, also, the mere lack of adequate historical information on the volume of migration dictates an assumption of no net migration. In making projections of national population for many, and possibly most, countries of the world, therefore, it is satisfactory to ignore this component, i.e., to assume that the net balance will be nil. This was the assumption employed in the set of country projections published by the United Nations in 1958.[51]

As was noted in chapter 20, however, in a fair number of cases, net migration constitutes at least 10 percent of net population change. In the case of Australia (net immigration) and Ireland (net emigration), it is a major factor in population change. Moreover, even though the volume of net migration is small, population projections by age may be strongly affected because of the special sex-age composition of the migrants. It is desirable, therefore, to allow for net migration in some cases.

The allowance for international migration may be an arbitrary rounded amount, roughly in line with recent experience, which is assumed to remain constant for the duration of the projection period. If the calculations are done by age and sex, a constant age-sex distribution may also be assumed. Alternatively, a constant rate of migration may be assumed or the amount or rate of net migration may be projected on the basis of the recent trend. The age-sex distribution of migrants is unlikely to resemble the population of the sending or receiving country, young adult males tending to be overrepresented among migrants. Therefore, the age-sex distribution is best taken from an available distribution for recent migrants.

To simplify the computations, the migrants may be added to or subtracted from the population at the end of the year of entry or departure or, less precisely, the quinquennium of entry or departure. This simple assumption eliminates the need of allowing for deaths or births of the migrants during the period of entry or departure (the average period of exposure to the risk of birth and death being one-half of each projection period). At the same time, the age distribution of the migrants should be adjusted to reflect the change in age between the date of migration and the end of the migration period. Following the period of arrival, the same birth rates and death rates may be applied to the immigrants as to the general population. Any difference in the level of fertility or mortality of the general population and the immigrant population would have very little effect on the future population. These simplifying assumptions eliminate the need for special calculations of fertility rates and survival rates, and special adjustments of the data on migrants.

The projections of the population of Great Britain made by the Royal Commission in 1947 employed two series of migration projections, each of fixed absolute amounts.[52] Net immigration was assumed for some population series and net emigration was assumed for others because of the great uncertainty regarding the prospects in the postwar recovery period. Population projections for Australia from 1960 to 1975, made by Borrie and Rodgers, employed three different assumptions regarding immigration:[53] (a) None, (b) constant annual amount, and (c) declining annual amount. Allowance was also made in these projections for the indirect effects of immigration on fertility rates. Since most arriving women were either wives or fiancees and since the surplus of adult males among the immigrants helped to increase the proportion of native Australian women (and of earlier immigrants) who were married, separate levels of age-specific fertility rates were used for the no-migration and with-migration assumptions.

The four principal series of projections published for the United States in 1967 each employed the same assumption of a constant annual net immigration of 400,000 from July 1, 1966, to July 1, 1990.[54] This number corresponds roughly to the volume of net immigration in the middle sixties. For the age and sex composition of net civilian immigration, the same allowance was used for each year in each series of population projections, corresponding to the distribution in 1961–64. The future additions to the population resulting from an annual net immigration of 400,000 persons between 1966 and 1990 may be determined by comparing projections assuming this amount of net immigration with projections assuming no migration, under the same fertility and mortality assumptions. Such a comparison, indicating the cumulative additions or losses by components of change, is given in table 24–15 for the projections with B level fertility and slightly declining mortality. The projected contribution of net immigration to population growth between 1966 and 1990 is 13.6 million; this is the total difference between the two series of population projections. Four hundred thousand (net) immigrants per year would cumulate to 9.6 million over 24 years, but over 4 million more would be added by the natural increase of the (net) immigrants in this period (4.6 million births less 0.6 million deaths).

The most recent national projections prepared at the United Nations illustrate the projection of a changing amount of migration. For a few countries (in Europe, the Americas, and

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[50] Akers, op. cit., p. 427; Siegel and Akers, op. cit., p. 114.

[51] United Nations, *The Future Growth of World Population*, p. 40.

[52] Great Britain, Royal Commission on Population, op. cit. p. 216.

[53] W. D. Borrie and Ruth Rodgers, *Australian Population Projections: 1960 to 1975*, Department of Demography, Australian National University, Canberra, August 1961.

[54] U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 381, p. 42.

Table 24-15.—Future Additions to the Population of the United States Resulting From an Annual Net Immigration of 400,000 Persons, By Components: 1966 to 1990

[Numbers in thousands. Based on projections assuming an intermediate (B) level of fertility and slightly declining mortality. Population series with immigration assumes that immigrants do not have births or die during the year of arrival. Base date is July 1, 1966]

Year (July 1)	Cumulative additions or losses					Additions or losses during preceding period			
	Net additions		Births	Deaths	Net immigration	Net additions	Births	Deaths	Net immigration
	Number	Percent of total population[1]							
1970	1,697	0.8	107	10	1,600	1,697	107	10	1,600
1975	4,183	1.9	652	67	3,600	2,486	545	57	2,000
1980	7,026	2.9	1,605	177	5,600	2,843	953	110	2,000
1985	10,179	3.8	2,929	347	7,600	3,153	1,324	170	2,000
1990	13,626	4.8	4,616	588	9,600	3,447	1,687	241	2,000

[1] Base is population including allowance for net immigration on date indicated.

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 381, "Projections of the Population of the United States, by Age, Sex, and Color to 1990, With Extensions of Population by Age and Sex to 2015," Dec. 18, 1967, table DD, p. 43.

Oceania), assumed annual amounts of net immigration for the initial period (1960-80) were projected linearly to zero between 1980 and 2000.[55]

Because it is often impossible to arrive at a satisfactory measure of past trends in the volume and age-sex distribution of net migration and because it is extremely difficult in most cases to predict the future course of migration with any confidence, model allowances and model tables may be employed to allow for this component. These may either be incorporated into the principal population projections, or they may be computed and displayed separately from those projections. The model can be used to measure the effect of any given annual amount of migration upon the population figures for the various sex-age groups. A model may be applicable to a group of countries in a particular geographic region, although it may be based on the statistics of recent immigration and emigration for a single country. Other models, suited to different situations, can be developed by the same methods. The U.N. projections for Latin America were accompanied by a model which could be used to estimate the effect of any given annual amount of immigration and emigration upon the sex-age distribution for various countries in Latin America.[56] The model is based on the statistics of postwar (1948-52) immigration and emigration for Argentina; it presents the effects of immigration at the rate of 100,000 a year and emigration at 25,000 a year, with an annual net immigration of 75,000. The effect of any alternative amount of net immigration or net emigration may be determined by inflating or deflating the model figures proportionately; i.e., halving the figures if only 37,500 net immigration is to be assumed.

Normally, the two components of international migration, immigration and emigration, are projected in combination as net migration. Consideration may be given to projecting immigration and emigration separately when separate trends in these components can be identified and net migration is sufficiently large. Even when there is an overall balance of roughly zero net migration for a population, there may be substantial gross migration and, under these circumstances, the contribution of immigration and emigration to the gross migration may vary from one age to another. If the age-sex distributions of immigrants and emigrants differ considerably, there may be reason to project, and evaluate the effect of, immigration and emigration separately. Projections for West Germany made in 1963 provided one alternative with net immigration through 1969 but added a table giving the survivors and descendants annually over a period of 40 years of 100,000 immigrants and 100,000 emigrants by sex.[57]

United Nations Projections of 1966.—The population projections for the countries of the world published periodically by the United Nations represent the single most important set of international population projections available. We describe these projections here as an illustration of how the components of population change may be combined in developing a comparable set of population projections. In its latest set of population projections, those published in 1966, the United Nations applied the same method uniformly for every world region in order to achieve a certain degree of interregional comparability, even though the methods are too crude for some areas and too refined for others.[58]

These projections employed the U.N. set of model life tables, which provide a representative set of survival rates for any general mortality level defined in terms of $\mathring{e}_0$. These generalized assumptions were modified where this was considered appropriate, and for particular countries expectation of life at birth could exceed the limit of 73.9 years assumed for the set of model tables. The system calls for a steady decline in mortality in the future in all countries; no increase in mortality is contemplated. The amount of plausible variation in death rates in most regions of the world appears rather small, compared with that for birth rates, and so only one mortality assumption was employed to carry out the projections for most regions. In the case of the remaining regions, however, high and low assumptions of mortality were employed.

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[55] United Nations, *World Population Prospects as Assessed in 1963*, pp. 46-47.

[56] United Nations, *The Population of South America, 1950-1980*, Annex C; and United Nations, *Methods for Population Projections by Sex and Age*, tables 47-50, pp. 64-67.

[57] Karl Schwarz, "Vorausschätzung der Bevölkerung des Bundesgebietes bis zum Jahr 2000" (Projections of the population of West Germany to the year 2000), *Wirtschaft und Statistik* (Wiesbaden), 12:729-735, Dec. 1963.

[58] United Nations, *World Population Prospects as Assessed in 1963*, pp. 44-48.

The use of a generalized procedure of allowing for mortality introduces some error, particularly where the "trend" of the model tables is not consistent with the actual past trend in a given country, or even with the actual current level in the country if it were known. Other errors may be more serious as, for example, the inadequacies of data on the age distribution from which the projections "take off."

The assumptions on fertility are stated in terms of the U.N. sex-age-adjusted birth rate (*s.a.a.b.r.*). Assumptions on fertility were formulated differently for regions with gross reproduction rates greater than 2.00 and those with gross reproduction rates less than 2.00. Most of the world's population has high fertility, which may very well decline by the year 2000, but there is little basis for formulating specific assumptions. For these high fertility regions (i.e., with *GRR* greater than 2.00), it was assumed that fertility would begin to fall at various dates before 2000 as follows: Taking general account of the record of other countries which have already experienced a decisive fertility decline, the *s.a.a.b.r.* in successive 5-year periods following onset of the decline was assumed to average 97.5, 90, 80, 70, 60, 52.5, and 50 percent of its initial value and to remain thereafter at this level (i.e., after a 30-year period). Alternative high, medium, and low assumptions were made for each region in terms of the assumed date of onset of the fertility decline, and the alternative dates were set wider apart in some regions than in others. In the high assumption the date of onset was assumed to be later than in the low assumption. (The rate, duration, and ultimate level of fertility were assumed to vary from this general assumption in some cases.)

For the regions of low fertility (i.e., with *GRR* less than 2.00), the high, medium, and low assumptions were based on an examination of variations previously observed in these regions. For the high assumption, the *s.a.a.b.r.* was assumed to average 20 from 1970 onward in regions of very low fertility and 25 per 1,000 in regions of moderately low fertility. For the low assumption, the *s.a.a.b.r.* was assumed to fall to between 16 and 18 in 1970.

Allowance for net migration was limited to those regions where the recent volume of net migration had been relatively large in proportion to the natural population increase—Europe, the Americas, and Oceania. The principal assumption was that, in the period 1960 to 1980, there would be a fixed annual migratory loss from Europe of 230,000 to America and Oceania; between 1980 and 2000, the migratory balance would diminish linearly to zero. (The assumption comprises a net immigration, presumably mostly from Europe, of 40,000 annually to Temperate South America, and an equally large net emigration, presumably mostly to the United States, from the Caribbean and the Middle American mainland.) It was further assumed that an annual migratory balance of 1,000 persons would entail a demographic gain (or loss) of 12,000 persons within the first 10-year period, and 15,000, 18,000, and 20,000 in each of the next three 10-year periods. These additions (or losses) represent the combination of the direct additions due to net immigration and the indirect additions through the natural increase of the migrants.

Three sets of projections are presented for the world, major areas, and regions, labeled "medium," "high," or "low," based on census data or estimates of total population and age-sex composition for years around 1960. The individual series generally represent the combination of high, medium, or low fertility with the single assumption on mortality and migration. In the few regions where high and low assumptions of mortality were employed, these were combined with either high or low fertility depending on the circumstances in each region. In general, only one set of projections, corresponding to the medium variant, is presented for each country. The medium series is intended to follow the most plausible population trend, and the high and low series are designed to represent upper and lower boundaries of the range of maximum plausibility or estimates of the range of error in the medium series. This range varies from region to region. A fourth series, "constant fertility, no migration," allowing for mortality improvement, is designed to serve as a basis for evaluating changes in the other series. Available (official) national projections, extrapolated if necessary to 1980, were generally employed for individual countries.

Subnational Projections of Total Population and Age-Sex Composition

In turning from the methodology of national projections to the methodology of projections for geographic subdivisions, we must become concerned with the outlook for internal migration. Although the assumption that future international migration will be nil or negligible is justified for many countries, internal migration (particularly rural-urban migration) involves a large proportion of the people in almost all countries. Indeed, as we saw in chapter 13, the growth rates of a country's political subdivisions tend to differ largely because of internal migration rather than natural increase.

The problem of making population projections is rather different for political units, such as States and counties, and for subdivisions that represent statistical classifications, such as urban-rural areas and areas classified by size. As was noted in chapter 6, the former are subject to relatively few boundary changes, whereas the latter are frequently reclassified after the results of each census become available. Changes in population resulting from boundary changes and revised statistical classifications constitute, in effect, another major component along with migration which must be considered in making projections for these areas. We will consider here only the methods of projecting population for relatively stable, political areas not affected by boundary changes.

The range of methods applicable to subnational projections is more extensive than for national projections. This situation results from the fact that both independent methods and methods dependent on the projection for another area (either another geographic subdivision or, more commonly, the country as a whole) may conveniently be employed in the calculation, from the fact that the methodology must consider internal migration as an additional factor, and from the fact that many types of data are relevant and often available. Although internal migration is often an important factor in local population growth, and it must be taken account of in projections, the allowance for this factor does not have to be explicit. The various methods for subnational projections include mathematical methods and ratio methods; cohort-component methods; methods using economic analysis, particularly correlation with "indicators," i.e., variables whose changes more or less reflect changes in population; and combinations of these methods. The various analytic methods attempt to take explicit account of one or more of the demographic or socioeconomic variables with which change in the geographic distribution of the population is related. Once again, because some methods derive the projections of total population by combining projections for age groups and because others may be applicable for deriving projections of both total population and age-sex structure directly, it is convenient to consider the projection of total population and age-sex structure at the same time.

Mathematical and Ratio Methods.—We consider first those methods which employ a minimum of independent data, assumptions, and variables for making the projections. Even when additional statistics, including estimates of past net migration, can be developed, one does not have to use the more complex, analytic methods, especially if projections must be prepared for a large number of geographic subdivisions and rough figures are satisfactory. In the mathematical methods, as previously noted, typically the series of total population figures for past years for the area are directly extended to future years by use of some mathematical formula, without benefit of other related series of projections. In the ratio procedures, typically the series of total population figures for past years are extended by mathematical formula as a ratio of the population for some larger area for which population projections are already available. Sometimes the two methods may be applied in such a way as to imply algebraically nearly the same procedure and give the same results; for example, projections for a set of geographic areas derived by mathematical extrapolation of absolute totals and *pro rata* adjustment of these extrapolated figures to prior projections of the parent (i.e., more inclusive) population may closely resemble projections obtained by the ratio method.

Mathematical methods.—The forms of mathematical curves useful for making projections of local population are very much the same as those useful for making national projections, as noted earlier and as described in chapters 13 and 22. Local populations may be projected by straight lines, simple geometric curves, polynomials of second or third degree, or complex growth curves such as the logistic curve. The curves may be passed exactly through the past data or simply approximate them. The particular curves differ in their suitability for particular situations or in the probable errors associated with the results. Special caution is necessary in the use of mathematical curves for projection purposes. A mathematical curve may project an unreasonably large figure for a local area in relation to a prior projection for the parent area and, in extreme cases, may project a larger figure, even with the same mathematical curve. None of the curves, except possibly the logistic, is applicable over a long period because they imply either unlimited growth or indefinite continuation of the same growth pattern.

Ratio methods.—The ratio method of projecting total population is peculiar to projections for geographic subdivisions. In this method the percentage distribution of the parent population (e.g., a country) among the geographic subdivisions (e.g., States) is observed for one or more past dates, projected to future dates, and applied to an independently derived projection of the parent population. For the projection of the percents, the percent distribution may be held constant at the last observed level or may be modified in some way to take account of the past trend. Although, in principle, the chief factor affecting the redistribution of population is internal migration and this component of change is quite likely to be influenced by economic developments, there is no direct practical way of taking account of plans or expectations concerning the economic development of regions in the ratio method. The percent distribution may be assumed to approach a stable condition after a great number of years on the ground that differences in fertility and mortality will have disappeared and net migration will have fallen off to zero for each area. There are many ways of accomplishing a shift to stability in this distribution.

One procedure for calculating projections by the ratio method may be illustrated for the provinces of Canada (table 24–16). These projections assume that the average annual rate of change in the percents observed between June 1, 1961, and June 1, 1969, for each area will fall off linearly to zero by the year 2,025.[59] First, the percent distributions of the national population by provinces in 1961 and 1969 are calculated (cols. 1 and 2). Second, the average annual rates of change between 1961 and 1969 are derived (col. 3). They are assigned to the middate of the period, Dec. 1965. These rates of change are then extrapolated according to the basic assumption noted above (cols. 4 to 9 and cols. 13 to 17). The population percents of June 1969 are then extrapolated to 1975 (col. 10) and 1980 (col. 18) according to the annual percent changes previously determined for each projection year. These percents do not automatically add to 100.0 and require some adjustment (cols. 11 and 19). Finally, in columns 12 and 20 the absolute figures are obtained by multiplying the percents by an independently derived projection of the total population of the country.[60]

Another variation of the ratio method employs an assumed relationship between the area's own growth rate and that of another area for which a projection is already available. In this case the other area may be a broader area or a coordinate geographic subdivision. The method is especially applicable when (a) adequate population and vital statistics are lacking for a given area, (b) data are lacking for part of an area's population, for example the tribal or nomadic population, or (c) the relatively small population of the area or the limited time available make it impractical to construct an independent projection.

The ratio method in either form may also be used, of course, when a single geographic subdivision requires a population projection. Moreover, it is readily capable of extension to a hierarchy of subdivisions. For example, having been used for states or provinces, it may next be used for the counties or communes of which these primary subdivisions are constituted; in this case, the projections for the primary subdivisions are employed as totals to which the secondary set of percentage distributions is applied.

The ratio method may be readily adapted to derive projections of the age-sex distribution of geographic subdivisions. Two types of ratio techniques are considered here for projecting the age-sex distribution of the primary divisions of a country. Both require prior projections of the national population by age and sex and of the total population of each area. The first employs the ratio of the percent of the area's population in each age-sex group to the corresponding percent for the national population at the last census.[61] It is then assumed that the ratios of the percents will not change, will change according to the intercensal "trend," or will change according to some other principle, as for example, that the ratios will approach unity by some distant date. The projected ratios are then applied to the projections of the percent distribution of the

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[59] All calculations are actually carried out in terms of proportions rather than percents (i.e., on a unit basis).

[60] An alternative briefer method of projecting the ratios is illustrated in: Helen R. White, J. S. Siegel, and Beatrice M. Rosen, "Short Cuts in Computing Ratio Projections of Population," *Agricultural Economics Research*, 5(1):5–11, January 1953.

[61] For an application of this method, see Margaret J. Hagood and J. S. Siegel, "Projections of the Regional Distribution of the Population of the United States to 1975," *Agricultural Economics Research*, 3(2):41–52, April 1951.

Table 24–16.—Projection of the Population of the Provinces of Canada by the Ratio Method from 1969 to 1975 and 1980

Province	Percent distribution of population[1]		Average annual rate of change in percent[2]							Preliminary percent distribution, June 1, 1975
			Estimated, 1961-69	Projected						
	Census, June 1, 1961 (1)	Estimates, June 1, 1969 (2)	(3)	1969-70 (4)	1970-71 (5)	1971-72 (6)	1972-73 (7)	1973-74 (8)	1974-75 (9)	(10)
Canada	100.000	100.000	(X)	(X)	(X)	(X)	(X)	(X)	(X)	100.166
Newfoundland	2.510	2.441	-0.349	-0.322	-0.316	-0.310	-0.304	-0.298	-0.292	2.399
Prince Edward Island	0.574	0.522	-1.188	-1.093	-1.072	-1.051	-1.030	-1.009	-0.988	0.489
Nova Scotia	4.041	3.623	-1.365	-1.257	-1.233	-1.209	-1.185	-1.161	-1.137	3.371
New Brunswick	3.278	2.968	-1.241	-1.142	-1.120	-1.098	-1.076	-1.054	-1.032	2.780
Quebec	28.836	28.413	-0.185	-0.171	-0.168	-0.165	-0.162	-0.159	-0.156	28.074
Ontario	34.192	35.383	+0.428	+0.396	+0.389	+0.382	+0.375	+0.368	+0.361	36.241
Manitoba	5.054	4.648	-1.046	-0.965	-0.947	-0.929	-0.911	-0.893	-0.875	4.399
Saskatchewan	5.073	4.553	-1.351	-1.247	-1.224	-1.201	-1.178	-1.155	-1.132	4.239
Alberta	7.303	7.412	+0.185	+0.171	+0.168	+0.165	+0.162	+0.159	+0.156	7.502
British Columbia	8.932	9.814	+1.178	+1.088	+1.068	+1.048	+1.028	+1.008	+0.988	10.437
Yukon and Northwest Territories	0.206	0.223	+0.991	+0.914	+0.897	+0.880	+0.863	+0.846	+0.829	0.235

Province	Projected population, June 1, 1975		Projected average annual rate of change in percent[2]					Projected population, June 1, 1980		
								Percent distribution		
	Adjusted percent distribution (11)	Number (12)	1975-76 (13)	1976-77 (14)	1977-78 (15)	1978-79 (16)	1979-80 (17)	Preliminary (18)	Adjusted (19)	Number (20)
Canada	100.000	[3]23,256,025	(X)	(X)	(X)	(X)	(X)	100.162	100.000	[3]25,250,634
Newfoundland	2.395	556,982	-0.286	-0.280	-0.274	-0.268	-0.262	2.360	2.356	594,905
Prince Edward Island	0.488	113,489	-0.967	-0.946	-0.925	-0.904	-0.883	0.464	0.463	116,910
Nova Scotia	3.365	782,565	-1.113	-1.089	-1.065	-1.041	-1.017	3.187	3.182	803,475
New Brunswick	2.775	645,355	-1.010	-0.988	-0.966	-0.944	-0.922	2.645	2.641	666,869
Quebec	28.027	6,517,966	-0.153	-0.150	-0.147	-0.144	-0.141	27.831	27.786	7,016,141
Ontario	36.181	8,414,262	+0.354	+0.347	+0.340	+0.333	+0.326	36.764	36.704	9,267,994
Manitoba	4.392	1,021,405	-0.857	-0.839	-0.821	-0.803	-0.785	4.214	4.207	1,062,294
Saskatchewan	4.232	984,195	-1.109	-1.086	-1.063	-1.040	-1.017	4.011	4.005	1,011,288
Alberta	7.490	1,741,876	+0.153	+0.150	+0.147	+0.144	+0.141	7.544	7.532	1,901,878
British Columbia	10.420	2,423,278	+0.968	+0.948	+0.928	+0.908	+0.888	10.897	10.879	2,747,016
Yukon and Northwest Territories	0.235	54,652	+0.812	+0.795	+0.778	+0.761	+0.744	0.245	0.245	61,864

X Not applicable.

[1] Sources of basic data: Canada, Dominion Bureau of Statistics, *Census of Canada, 1961*, Vol. I (Part 1), *Population: Geographical Distribution*, 1962; and idem, "Estimated Population by Sex and Age Group, for Canada and Provinces," June 1, 1969, Dec. 1969.

[2] Rate for 1961–69 derived from the percent distributions for 1961 and 1969. Rates for 1969–70 to 1979–80 derived by linear interpolation between the rate of change for the period 1961–69 (with July 1, 1965 as the assumed central date) and the rate for the period 2020–25, which is assumed to be zero in every case.

[3] Derived by adjusting the projections given in, Wolfgang M. Illing, *Population, Family, Household and Labor Force Growth to 1980*, Staff Study No. 19, prepared for the Economic Council of Canada, Sept. 1967, table 2-7 (series with medium immigration and medium fertility).

population by age for the country as a whole to obtain projections of the percent distribution by age for each area. Each of these percent distributions must then be proportionately adjusted to 100 percent for all ages before being applied to projections of the total population of each area. Proportionate adjustments of the figures for all areas at each age to the national totals at that age, and of the age-sex figures for each area to the total of all ages for the area, follow in order. This cycle of adjustments is repeated until full, or nearly full, agreement with marginal totals is obtained (known as the method of iterative proportions or two-way raking; see ch. 22).

Two-way raking is also applied in the second ratio procedure for projecting the age-sex distributions for a set of subnational areas. Here, the male population and the female population at each age in the parent population at the first projection date are distributed by geographic areas according to the regional distribution at the last census, and the results over all ages are then adjusted proportionately to the independent projection of the total population of each area. The resulting figures are again subjected to the same adjustment cycle until complete reconciliation with assigned marginal totals has been achieved. These final results are then utilized as a basis for deriving the projections at the next projection date by the same procedure, and so on. This two-way raking procedure has been applied principally in connection with projections of the urban and rural population by age and sex (see app. A).

These two ratio techniques may be effectively merged into a single procedure. Consider the case where data on age, sex, and geographic subdivisions are available for a single census and it is assumed that the sub-area-to-total-area ratios of the percents for each age group will remain unchanged from one projection date to the next. The final figures for the first projection year, after raking is completed, may then be employed as a basis for calculating the ratios of the percents to be used in the second projection year, and so on.[62]

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[62] A step-by-step description of this procedure, including applications to the countries of Central America, is given in: United Nations, Economic Commission for Latin America, *Human Resources of Central America, Panama, and Mexico, 1950–80, in Relation to Some Aspects of Economic Development*, by Louis J. Ducoff, 1960, app. B and pp. 41–45.

In sum, the mathematical and ratio methods of projecting regional population generally have the advantage of simplicity of computation, but they do not take into explicit account, and hence provide little or no information with respect to, the demographic or socioeconomic correlates or components of the indicated trends. Nevertheless, the results may usefully serve as approximations to the future geographic distribution of the population of an area, particularly when comparable figures for a set of constituent areas are desired quickly and with little investment of resources.

Cohort-Component Method.—The cohort-component method is now the most widely used of the analytic methods for preparing regional projections. The general outline of the method is the same as indicated for national projections, but the component of internal migration must be incorportated into the procedure. This method is especially appropriate if projections by age and sex are wanted in addition to totals. Carrying out component projections on an age-specific basis is recommended even when projections of only the total population are sought, because of the added specificity of the assumptions and the provision of data on the age-sex distribution of the population as a by-product. The cohort-component method may be applied with various degrees of refinement and complexity, from a variation in which mortality and migration are handled jointly and a single assumption is made for this joint component, to one in which migration is treated as three components, namely, net immigration, gross in-migration, and gross out-migration, and several assumptions are made with respect to each component of change. In applying the cohort-component method, the choice of a specific procedure is suggested in large part by the type and quality of data available and the resources for developing the projections.

Sufficient testing has not been carried out to support the conclusion that the analytic methods, including the cohort-component method, provide more accurate or realistic projections than the ratio and mathematical methods, but they may be preferred for a number of reasons, quite apart from the relative accuracy of the methods. As in the case of national projections, they may be expected to provide more meaningful and useful results for subnational areas since they attempt to take explicit account of the components of change and of available knowledge regarding the course of these components. In addition, direct use can be made of national projections of mortality, fertility, and net migration from abroad. From the standpoint of accuracy, however, the choice of method may be less important than the choice of assumptions, particularly those relating to individual components. Like any set of projections based on recent past trends, projections using the cohort-component method will fail to predict a shift away from these trends during the projection period and, hence, may differ from actual developments.

Use of census cohort-change rates.—In the simplest form of the cohort-component method the components of net migration and mortality are treated as a unit in the projections for the cohorts already alive at the base date, and a single assumption is made that the rates remain unchanged. In general, the method involves carrying forward the latest census or current population by age and sex to future years by use of census cohort-change rates (sometimes called migration-survival ratios), representing the ratio of the number of persons enumerated in a given age group in one census to the number of persons in the same birth cohort enumerated in a previous census. Census cohort-change rates include, in addition to mortality and net migration, the effect of relative errors of enumeration between successive censuses. In the formula of Hamilton and Perry cohort-change rates for a given area between the two censuses are assumed to remain constant in future years:[63]

$$ {}_nP_{a+k}^{t+k} = \frac{{}_nP_{a+k}^{t}}{{}_nP_{a}^{t-k}} \, {}_nP_{a}^{t} \qquad (8) $$

where P is population, a is the initial age of the age interval at the second census, n is the size of the age interval, t is the year of the second census, and k is the intercensal interval in years (a multiple of n, usually 5 or 10 years). The formula does not directly allow for the calculation of projections of children in the cohorts born during the intercensal period. In the Hamilton-Perry procedure births during the projection period are estimated by holding constant recent age-specific birth rates. In our illustration below, we hold constant the last observed child-women ratio. Although formula (8) assumes no change from the intercensal period to the projection period in age-specific death rates, migration rates, and patterns of net census error, alternative assumptions are possible.

Censuses are taken most commonly at 10-year time intervals and show abridged age detail for geographic subdivisions of the country. In this case, it is most convenient to prepare projections at 10-year time intervals for a combination of 5- and 10-year age groups (depending on the original age detail). An illustration, relating to Sivas Province in Turkey, employs census data for 1955 and 1965, to derive projections for the female population in 5- and 10-year age groups for 1975 (table 24–17). The age data shown for 1955 and 1965 represent the maximum common detail available in these censuses, and projections for the same age groups were prepared. Census data are also available for 1960 but were disregarded for this illustration. No adjustments were made for errors in coverage or age reporting in the 1955 and 1965 censuses. To adapt to the age detail available, we have calculated 10-year census cohort-change rates for 5-year age groups up to 20–24 and for 10-year age groups 25 and over; for example,

$$ P_{20\text{-}24}^{1975} = \frac{P_{20\text{-}24}^{1965}}{P_{10\text{-}14}^{1955}} \cdot P_{10\text{-}14}^{1965} $$

$$ P_{25\text{-}34}^{1975} = \frac{P_{25\text{-}34}^{1965}}{P_{15\text{-}24}^{1955}} \cdot P_{15\text{-}24}^{1965} $$

$$ P_{65+}^{1975} = \frac{P_{65+}^{1965}}{P_{55+}^{1955}} \cdot P_{55+}^{1965} $$

For the ages under 10 in 1975, we have employed the following ratios of children to women:

$$ P_{0\text{-}4}^{1975} = \frac{P_{0\text{-}4}^{1965}}{P_{15\text{-}54}^{1965}} \cdot P_{15\text{-}54}^{1975} $$

$$ P_{5\text{-}9}^{1975} = \frac{P_{5\text{-}9}^{1965}}{P_{20\text{-}54}^{1965}} \cdot P_{20\text{-}54}^{1975} $$

Where the censuses are five years apart and 5-year age data are available for the geographic units, projections can conveniently be made at 5-year time intervals for 5-year age groups

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[63] C. Horace Hamilton and Josef Perry, "A Short Method for Projecting Population by Age From One Decennial Census to Another," *Social Forces* 41(2):163–170, Dec. 1962.

Table 24-17.—**Projection of the Female Population of Sivas Province, Turkey, by Age, by the Census Cohort-Change Method (10-Year Intercensal Period), from 1965 to 1975**

Age (a) (years)	Census, 1955[1] (1)	Census, 1965[1] (2)	Ratio $(2)_a \div (1)_{a-10} =$ (3)	Projected population, 1975 $(3)_a \times (2)_{a-10} =$ (4)
Total..........	300,383	354,809	(X)	418,741
0-4................	54,095	59,569	(X)	[2]71,992
5-9................	41,990	55,957	(X)	[2]66,156
10-14..............	27,566	41,585	.7687	45,791
15-19..............	25,757	29,291	.6976	39,036
20-24..............	28,216	25,455	.9234	38,400
25-34..............	47,127	55,516	1.0286	56,312
35-44..............	28,831	35,614	.7557	41,953
45-54..............	23,040	22,028	.7640	27,209
55-64..............	14,446	18,347	.7963	17,541
65 and over........	9,315	11,446	[3].4817	[4]14,351

X Not applicable.

[1] Sources: Turkey, General Statistical Office, *Census of Population, Oct. 23, 1955, Population of Turkey*, Vol. 67, table 16; idem, *Census of Population, Oct. 24, 1965, Social and Economic Characteristics of the Population*, table 12. Ages not reported have been prorated.

[2] Calculated by special formula; see text.

[3] Derived by: 11,446 ÷ (14,446 + 9,315).

[4] Derived by: .4817 (18,347 + 11,446).

by census cohort-change rates, except for young children. The projections for children under 5 in the first projection year can be derived by assuming that the ratio of children to women of childbearing age in that year and later years will be the same as shown by the latest census. We can also carry out this procedure for Sivas Province in Turkey using the census data for 1960 and 1965. The steps are: (1) Subdivide the 10-year data for ages 25 and over into 5-year age groups (chapters 8 and 22), (2) carry the population forward to 1970 and 1975 in 5-year age groups by the cohort-change method, and then (3) recombine the data into the age groups of the census. Table 24–18 presents the calculations for part of the age distribution and the resulting total over all ages. The age groups above age 25 were subdivided by osculatory interpolation (Sprague multipliers) in order to derive the required 5-year cohort-change rates. The projections for children under 5 in 1970 and 1975 were based on the assumption that:

$$\left(\frac{P_{0-4}}{P_{15-49}}\right)^{1965} = \left(\frac{P_{0-4}}{P_{15-49}}\right)^{1970} = \left(\frac{P_{0-4}}{P_{15-49}}\right)^{1975}$$

A comparison of the projections for 1975 in tables 24–17 (col. 4) and 24–18 (col. 5) indicates substantial percentage differences at a few ages under 35. The differences may be viewed as reflecting principally the results of employing two different assumptions of net migration, although differences in mortality and in net census errors are also involved.

Direct estimates of net migration.—A more refined procedure, which we may call the **cohort migration-survival method,** treats migration as a separate component. In the most common variation, births, deaths, and net migration (combining net immigration and net internal migration) are the components directly manipulated. Although statistics of gross migration are useful in analyzing past population redistribution and in making more realistic assumptions about future migration (see next section), they may be unavailable and use of such data, when available, greatly complicates the method. The effect of migration on population change may be measured more simply by use of estimates of net migration. As we have seen in chapter

Table 24–18.—**Projection of the Female Population of Sivas Province, Turkey, by Age, by the Census Cohort-Change Method (5-Year Intercensal Period), from 1965 to 1970 and 1975**

Age (a) (years)	Census, 1960[1] (1)	Census, 1965[1] (2)	Ratio $(2)_a \div (1)_{a-5} =$ (3)	Projected population, 1970 $(3)_a \times (2)_{a-5} =$ (4)	Projected population, 1975 $(3)_a \times (4)_{a-5} =$ (5)
Total, all ages[2]...........................	333,851	354,809	(X)	376,504	401,574
Under 5....................................	56,616	59,569	(X)	[3]63,334	[4]68,179
5-9..	50,065	55,957	.9884	58,878	62,600
10-14......................................	36,303	41,585	.8306	46,478	48,904
15-19......................................	24,502	29,291	.8068	33,551	37,498
20-24......................................	26,779	25,455	1.0389	30,430	34,856
25-34......................................	(57,136)	(55,516)	(X)	(53,183)	(57,192)
25-29......................................	29,526	28,517	1.0649	27,107	32,405
30-34......................................	27,610	26,999	.9144	26,076	24,787
.					
.					
.					

X Not applicable.

[1] Sources: Turkey, General Statistical Office, *Census of Population, Oct. 23, 1960*, No. 452, table 5; idem, *Census of Population, Oct. 24, 1965, Social and Economic Characteristics of the Population*, table 12. Age not reported has been prorated. Age groups 25 and over were subdivided into 5-year age groups by osculatory interpolation (Sprague multipliers).

[2] Covers all ages, including 35 years and over.

[3] Calculated by use of the formula:

$$\frac{P_{0-4}^{1965\ (\text{census})}}{P_{15-49}^{1965\ (\text{census})}} \times P_{15-49}^{1970\ (\text{projected})}$$

[4] Calculated by use of the formula:

$$\frac{P_{0-4}^{1970\ (\text{projected})}}{P_{15-49}^{1970\ (\text{projected})}} \times P_{15-49}^{1975\ (\text{projected})}$$

21, such estimates, combining international and internal migration as well as the effects of boundary changes, are readily calculated as intercensal residuals for the political subdivisions of many countries. Amounts and rates of net migration by age can be derived for those areas which have age data in the appropriate detail in two appropriately spaced censuses. Amounts and rates of net migration can occasionally be computed also from census or sample survey data on place of residence at a fixed date prior to the census or survey.

A variety of choices are available for making assumptions regarding future migration for geographic subdivisions. The migration assumptions may be expressed in terms of amounts or rates of net migration. The amounts or rates assumed should be based on actual experience in some recent period in the specific local area; they may be held constant or projected according to some formula. Gradual change to half or some other proportion of the previous intercensal amounts or rates by some future date is a type of alternative assumption. To simplify the expression and application of the assumptions, rounded amounts or rates may be employed. Estimates of net migration by age for a current period, for use in population projections for local areas, may be computed in various ways, as described in chapter 21. Either actual death statistics, life table survival rates, or national census survival rates may be employed to make the allowance for mortality in a residual procedure. The "forward" formula is well adapted to the needs of projections. The estimated amounts of net migration may then be converted to rates for the purpose of projections by dividing them by the "expected" population, that is, the survivors, at the end of the intercensal period, of the initial population.

Accordingly, if the population is to be carried forward by 5-year time intervals with 5-year migration rates of this kind, we could proceed as follows: (1) Calculate or select appropriate 5-year survival rates for the first 5-year projection period; (2) carry forward the initial population to the end of the first period with these projected survival rates to derive the "expected" population; (3) make an allowance for net migration by applying rates of net migration to the "expected" population; (4) project the number of births or the number of children under 5; (5) repeat these calculations for each subsequent 5-year projection period.

It may be recalled that intercensal estimates of net migration by age derived as residuals by use of national census survival rates are presumably free of net census error. It is desirable to employ this method in order to measure the migration component more accurately when making assumptions regarding future net migration. We can also allow for subnational variations in mortality in census survival rates if data are available. On the other hand, the method necessarily incorporates the assumption that regional census-to-census cohort changes in net census errors are the same as the national figures.

Procedures for deriving projections of population by the cohort migration-survival method using census survival rates are illustrated for the female population of Sivas Province, Turkey. Projections of the population to 1975 by 5-year or 10-year age groups, based on the census data for 1955 and 1965 (disregarding the 1960 census) and conforming to the age data available from the 1965 census, are presented in table 24-19. The steps are as follows:

A. Derivation of net migration rates by age, 1955-65:

1. Calculate national census survival rates for the female population of Turkey, 1955-1965 (col. 2).

2. Apply these rates (col. 2) to the census population of Sivas Province in 1955 (col. 1) to derive the expected population 10 years older in 1965 (col. 3). (No allowance was made for regional variation in mortality levels.)

3. Subtract the survivors (col. 3) from the census population of Sivas in 1965 (col. 4) to derive the estimated net migration by age cohorts, 1955-65 (col. 5).

4. Derive the corresponding rates of net migration, 1955-65 (col. 6), by dividing the estimates of net migration (col. 5) by the expected population (col. 3). (These rates have an unusual age pattern in comparison with the age patterns of net migration rates observed elsewhere but have been accepted for the present use without modification.)

B. Projection of the 1965 population to 1975:

5. Calculate 10-year life-table survival rates from model table South No. 20 (col. 7), chosen on the basis of an analysis of national census survival rates for Turkey and reflecting some future improvement.[64] (Note, again, that no allowance was made for regional variations in mortality levels.)

6. "Survive" the 1965 census population (col. 4) to 1975 (col. 8) by use of the life-table survival rates (col. 7).

7. Calculate net migration for the 1965-75 period (col. 9) by multiplying the migration rates (col. 6) by the survivors in 1975 (col. 8). This procedure assumes that net migration rates will remain unchanged.

8. Add net migrants (col. 9) to the expected population (col. 8) to derive population projections for 1975 (col. 10).

Inasmuch as the birth statistics of Turkey are inadequate, we have developed our projection of the population under 10 years of age in 1975 on a different basis. We have simply assumed that the ratio of children under 10 to women 15 to 54 years old in 1975 is the same as that observed in 1965. This procedure encompasses the effect of fertility, mortality, and net migration in determining the size of these juvenile age cohorts.

Other assumptions of net migration should be employed to prepare additional series of population projections. We have assumed above that net migration rates were the same as observed in 1955-65. Possible additional assumptions are: (1) Net migration rates, 1955-65, reduced 25 percent; (2) net migration rates, 1955-65, increased by 25 percent; etc.

We could have employed national census survival rates in projecting the population of Sivas Province instead of life table survival rates. As we developed the projections above, net census error in one age group is carried down to the next age group over a projection period. Use of national census survial rates would help to keep the net census errors of the Sivas data in their original (1965) ages and, hence, increase the accuracy of the projected changes by age. This procedure imposes the pattern of change in net census errors by age cohorts between 1955 and 1965 for Turkey on the census data for Sivas Province. Implicitly, mortality in Turkey as a whole at the level of 1955-65 is assumed for 1965-75, without change.

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[64] Ansley J. Coale and Paul Demeny, *op. cit.* See also Paul Demeny and Frederic C. Shorter, *Estimating Turkish Mortality, Fertility, and Age Structure*, Publication No. 218, Faculty of Economics, University of Istanbul, Istanbul, 1968, pp. 8-28.

Table 24-19.—Projection of the Female Population of Sivas Province, Turkey, by Age, by the Migration-Survival Method (10-Year Intercensal Period), from 1965 to 1975

Age (a) (years) in 1955	Age (a) (years) in 1965	Age (a) (years) in 1975	Population of Sivas Province, census of 1955[1] (1)	10-year census survival rates, Turkey, 1955 to 1965 (2)	Expected survivors, 1965 (1)x(2)= (3)	Population of Sivas Province, census of 1965[1] (4)	Net migration, 1955 to 1965 (4)-(3)= (5)	10-year net migration rate (5)÷(3)= (6)	10-year life-table survival rate[2] (7)	Expected survivors, 1975 (4)x(7)= (8)	Projected net migration, 1965 to 1975 $(8)_a \times (6)_{a+10}$= (9)	Projected population, 1975 (8)+(9)= (10)
Total	Total	Total	300,383	(X)	(X)	354,809	(X)	(X)	(X)	(X)	(X)	432,132
(X)	(X)	0-9	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	[3]143,345
(X)	0-4	10-14	(X)	(X)	(X)	59,569	(X)	(X)	.9798	58,366	-11,837	46,529
(X)	5-9	15-19	(X)	(X)	(X)	55,957	(X)	(X)	.9926	55,543	-11,231	44,312
0-4	10-14	20-24	54,095	.9643	52,164	41,585	-10,579	-.2028	.9910	41,211	-4,632	36,579
5-9	15-19	25-34	41,990	.8744	36,716	29,291	-7,424	-.2022	.9867	54,019	-854	53,165
10-14	20-24		27,566	1.0403	28,677	25,455	-3,222	-.1124				
15-24	25-34	35-44	53,973	1.0451	56,407	55,516	-891	-.0158	.9809	54,456	-9,748	44,708
25-34	35-44	45-54	47,127	.9205	43,380	35,614	-7,766	-.1790	.9678	34,467	-4,894	29,573
35-44	45-54	55-64	28,831	.8905	25,674	22,028	-3,646	-.1420	.9331	20,554	-2,695	17,859
45-54	55-64	65-74	23,040	.9165	21,116	18,347	-2,769	-.1311	.8285	15,200	[4]-3,785	[4]16,062
55 and over	65 and over	75 and over	23,761	.5952	14,143	11,446	-2,697	-.1907	.4060	4,647		

X Not applicable.

[1] Ages not reported have been prorated.

[2] Computed from model life table for region South, level 20, given in, Ansley J. Coale and Paul Demeny, *Regional Model Life Tables and Stable Populations*, Princeton, N.J., Princeton University Press, 1966, p. 675.

[3] Calculated by use of the formula:

$$\frac{P_{0-9}^{1965\ (\text{census})}}{P_{15-54}^{1965\ (\text{census})}} \times P_{15-54}^{1975\ (\text{projected})}$$

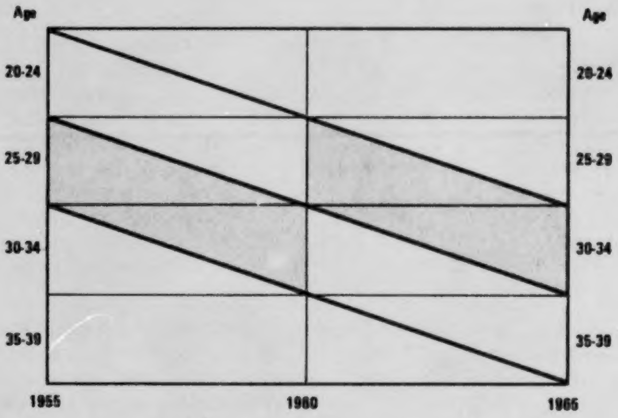
[4] Ages 65 and over.

Note that, ideally, we would adjust the 1965 census population of Sivas for net census errors by age and then carry the adjusted population forward by projected life table survival rates and net migration rates; a basis for adjusting the population is lacking, however.

Projections of population are often wanted at 5-year time intervals. A procedure for deriving projections of Sivas' population to 1970 is presented in table 24-20. It employs 10-year net migration rates estimated from the 1955 and 1965 censuses but requires a conversion of these 10-year rates to 5-year rates. (For purposes of this illustration also, we omit use of the 1960 census.) We assume that the 5-year net migration rates as estimated on the basis of 1955-65 population changes will continue unchanged for 1965-70. Having derived estimates of expected survivors in 1965, and of net migration for 1955-65 for 5-year age groups from 10 to 24 and 10-year age groups above age 25 (table 24-19, cols. 3 and 5), we can proceed as follows (table 24-20):

1. Subdivide the expected survivors in 1965 and the net migration estimates, 1955 to 1965, into 5-year age groups above age 25 (cols. 1 and 2). In the present illustration Sprague's osculatory multipliers (ch. 22) were employed for all categories except net migration 25 to 34 years. For the latter category, negative results were obtained by osculatory interpolation and Newton's interpolation formula for halving a group (ch. 8) was employed in its place.

2. Combine the population in adjacent ages (col. 3) and the estimates of net migration in adjacent ages (col. 4). The purpose of this step is to take advantage of the fact that the net migration of each 5-year age group is reflected in two of the cohorts employed in the calculations. For example, net migration for terminal ages 30-34 is represented by the two shaded areas in the following sketch:



3. Divide the net migration in column (4) by the population in column (3) to derive a hypothetical 10-year migration rate for 5-year age groups (col. 5).

4. Divide the results in column (5) by 2 to derive 5-year migration rates for 5-year age groups (col. 6).

5. Compute the expected female population of Sivas in 1970 (col. 9) by applying life-table survival rates (col. 8) to the census population in 1965 (col. 7).

6. Calculate the projected net migration for 1965-70 (col. 10) by applying the rates in column (6) to the expected survivors in column (9). In every case the figures are matched in terms of terminal ages.

7. Combine the projected net migration in column (10) with the expected survivors in column (9) to derive the projected population for 1970.

Table 24-20.—Projection of the Female Population of Sivas Province, Turkey, by Age, by the Migration-Survival Method (10-Year Intercensal Period), from 1965 to 1970

Age (a) (years)		Expected survivors, Sivas Province, 1965[1]	Net migration, 1955 to 1965[1]	$(1)_a + (1)_{a+5}$ =	$(2)_a + (2)_{a+5}$ =	10-year net migration rate	5-year net migration rate	Population of Sivas Province, census of 1965[2]	5-year life-table survival rate[3]	Expected survivors, 1970	Projected net migration, 1965 to 1970	Projected population, 1970
in 1965	in 1970					(4)÷(3)=	(5)÷2=			(7)x(8)=	$(9)_a \times (6)_{a+5}$=	(9)+(10)=
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Total........	Total........	(X)	(X)	(X)	(X)	(X)	(X)	354,809	(X)	(X)	(X)	386,525
(X)............	0-4............	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	[4]65,957
0-4............	5-9............	(X)	(X)	(X)	(X)	(X)	(X)	59,569	.98339	58,580	-5,940	52,640
5-9............	10-14..........	(X)	(X)	(X)	(X)	(X)	[5]-.1014	55,957	.99630	55,750	-5,647	50,103
10-14..........	15-19..........	52,164	-10,579	88,880	-18,003	-.2026	-.1013	41,585	.99625	41,429	-3,372	38,057
15-19..........	20-24..........	36,716	-7,424	65,393	-10,646	-.1628	-.0814	29,291	.99469	29,135	-961	28,174
20-24..........	25-29..........	28,677	-3,222	58,241	-3,848	-.0661	-.0330	25,455	.99327	25,284	-200	25,084
25-29..........	30-34..........	29,564	[6]-626	56,407	-891	-.0158	-.0079	28,517	.99211	28,292	-1,067	27,225
30-34..........	35-39..........	26,843	[6]-265	50,655	-3,819	-.0754	-.0377	26,999	.99069	26,748	-2,394	24,354
35-39..........	40-44..........	23,812	-3,554	43,380	-7,766	-.1790	-.0895	20,258	.98821	20,019	-1,954	18,065
40-44..........	45-49..........	19,568	-4,212	34,214	-6,681	-.1953	-.0976	15,356	.98443	15,117	-1,073	14,044
45-49..........	50-54..........	14,646	-2,469	25,674	-3,646	-.1420	-.0710	12,177	.97796	11,909	-551	11,358
50-54..........	55-59..........	11,028	-1,177	20,638	-1,912	-.0926	-.0463	9,851	.96781	9,534	-625	8,909
55-59..........	60-64..........	9,610	-735	21,116	-2,769	-.1311	-.0656	8,874	.94993	8,430	-768	7,662
60-64..........	65-69..........	11,506	-2,034	[7]18,578	[7]-3,383	-.1821	-.0911	9,473	.91659	[8]16,464	[8]-1,571	[8]14,893
65 and over....	70 and over....	14,143	-2,697	[9]14,143	[9]-2,697	-.1907	[10]-.0954	11,446	.67984			

X Not applicable.

[1] Age groups 25–29 to 60–64 were interpolated from 10-year age groups (cols. 3 and 5 of table 24–19) using Sprague's osculatory multipliers.

[2] Ages not reported were prorated. Age groups 25–29 to 60–64 were interpolated from 10-year age groups (col. 4 of table 24–19) using Sprague's osculatory multipliers.

[3] Model life table for region South, level 20, in, Ansley J. Coale and Paul Demeny, *Regional Model Life Tables and Stable Populations*, Princeton, N.J., Princeton University Press, 1966, p. 675.

[4] Calculated by use of the formula:

$$\frac{P_{0-4}^{1965\ (\text{census})}}{P_{15-49}^{1965\ (\text{census})}} \times P_{15-49}^{1970\ (\text{projected})}$$

[5] Net migration rate for ages 0–4 (initial) to 5–9 (terminal) assumed to equal one-half the net migration rate (−.2028) for ages 0–4 (initial) to 10–14 (terminal). See table 24–19, col. 6.

[6] Computed by applying Newton's interpolation formula for halving a group.

[7] Value for ages 60–64 plus one-half value for ages 65 and over in col. 1 or col. 2.

[8] Ages 65 and over.

[9] Same as value for ages 65 and over in col. 1 or col. 2.

[10] Net migration rate for ages 60 and over (initial) to 65 and over (terminal) assumed to equal one-half the net migration rate (−.1907) for ages 55 and over (initial) to 65 and over (terminal).

It will be noted in table 24–20 that the conversion of the data to 5-year time intervals was carried out after the estimates of 10-year net migration were derived since the latter should be calculated from unadjusted census data (assuming the use of national census survival rates). The derivation of 5-year amounts and rates of net migration for 5-year age groups, from 10-year amounts and rates for 5-year and 10-year age groups, may be accomplished in different ways. For example, we could interpolate our 10-year data to 5-year data at a different point in the calculations, as by converting the 10-year net migration rates directly to 5-year rates. This approach might improve on the procedure described earlier, which does not, in effect, handle the calculation of the denominator of the 5-year rates very satisfactorily. One could simply compute population projections for 10-year age groups 10 years ahead and derive other required figures by interpolation.

The results obtained for 1970 by the census cohort-change rate method and the cohort migration-survival method given in tables 24–18 and 24–20 differ substantially in many ages, as do the results for 1975 given in tables 24–17, 24–18, and 24–19. Differences in population projections for the same date reflect mainly differences in the underlying assumptions on net migration.

Tarver has presented a detailed illustration of the application of the cohort-component procedure to U.S. geographic subdivisions.[65] In his illustration 10-year intercensal amounts and rates of net migration, 1940–50, are derived by use of national census survival rates, adjusted for local mortality variations, and converted into 5-year amounts and rates of net migration for projecting the population from 1950 to 1955 and 1960. The procedure used for this conversion is largely the same as we applied to Sivas Province, Turkey. Estimates of net migration for children under 5 and 5 to 9 years of age are derived on the basis of statistics of births during the 1940–50 decade. The calculation of two alternative assumptions of net migration is also illustrated. The total amount of net migration derived initially for the 1940–50 period was reduced by 50 percent and 100 percent under the two assumptions. The corresponding figures by age under these assumptions were derived by applying a plus-minus proportionate adjustment procedure (described in ch. 22) to the amounts of net migration by age calculated initially. These 10-year amounts were converted to 5-year rates in the same manner as for the 100 percent assumption on net migration.

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[65] James D. Tarver, *A Component Method of Estimating and Projecting State and Subdivisional Populations*, Miscellaneous Publication MP-54, Oklahoma State University, Agriculture Experiment Station, 1959. See also James D. Tarver and Jeanie Hill, *IBM 650 Program Instructions for Making State, County, and City Population Projections by the Component Method*, Series P-353, Oklahoma State University, Agricultural Experiment Station, June 1960. The computer programs given relate to estimates and projections of birth rates, survival rates, net migration rates, births, and population for 5-year age groups for 5-year time periods.

Even if a country has good current data on internal migration, it is desirable for the responsible agency to prepare a special series of projections assuming no further net migration among the geographic subdivisions. In this way user agencies can make their own assumptions to serve special needs. Calculation of a series assuming no net migration among the geographic subdivisions of a country in future years permits an evaluation of the contribution of net migration to projected population change as reflected in the various series with net migration. In sum, a no-migration series may have considerable value to planners even though it may be quite unrealistic in itself.[66]

Projection of births and deaths.—We have already mentioned one or more ways of projecting births and deaths in preparing subnational population projections by the component method. We may consider this problem more generally.

Birth rates by age and survival rates (or age-specific death rates) may be projected independently, or by comparing the rates for the local area and its parent area for one or more past dates and applying the current or extrapolated ratio of these rates to previously available projections of the rates for the parent area. The parent area will usually be the country as a whole. In addition to historical analysis, an analysis of regional differences for other countries at various stages of economic development should prove useful in this regard.

Calculation of the number of births for each 5-year projection period by use of age-specific birth rates involves a special step. We have to interpolate the female population of childbearing age, by age, to the middle of each projection period, apply the projected age-specific birth rates cumulatively to this population to derive the average number of births in the period, and multiply this number by five to obtain the estimate for the 5-year period. Alternatively, births may be calculated for the first and last year of each 5-year projection period, added together, and then inflated by a factor of 2.5. The projected number of births and deaths over all subdivisions of an (parent) area should, as a final step, be adjusted to the projected total of births and deaths for the area.

Because birth and death statistics by age are not always available for small geographic areas and the volume of computations in the procedure just described is quite large, it is desirable or necessary to try to abbreviate the procedure. Fertility may be projected by an indirect method, such as one employing a single schedule of age-specific birth rates and projected total fertility rates, or sex-age adjusted birth rates. Mortality may also be projected by an indirect method, involving a single set of age-specific death rates but with some "control" figures at the local level. When mortality varies only moderately among the local areas, the same mortality rates may be assigned to several areas or even to all areas in a country. The projections for geographic subdivisions can be made in terms of the ratio of crude birth rates and crude death rates for the local areas to the corresponding figures for the country as a whole, provided there have been no radical changes in the age composition of local areas and carefully prepared national projections of births and deaths are available.[67]

Because of the possibility of substantial differences between the fertility of regions, consideration must be given to the question whether migrants will be assigned the fertility rates of their area of origin or the fertility rates of their area of destination during the period of their arrival and subsequently.

Separate projection of in- and out-migration.—More meaningful and possibly more realistic projections of internal migration may be derived by projecting in- and out-migration separately when the appropriate data are available, rather than net migration. This is because the variation in the relation of in-migration to out-migration, i.e., net migration, may be expected to be much greater than the variation in the corresponding gross in- or out-migration. Furthermore, total inmigration between geographic units in a country is in a sense dependent upon total out-migration from these units and projections for these totals can be made equal to one another very simply when in- and out-migration are projected separately. On the other hand, use of net migration rates often results in serious imbalances between total net in-migration and net outmigration. One general approach for projecting in- and outmigration separately employs age-specific out-migration rates to derive figures for out-migrants for each area and the distribution of the resulting total number of out-migrants among the several areas to derive estimates of in-migrants. This general approach was used in preparing projections of the population of States of the United States published in 1967, metropolitan areas of the United States in 1969, and communes of Sweden in 1969.[68]

A description of the methodology used in preparing the projections for the States of the United States, by age and sex, from 1965 to 1985, will serve to illustrate a cohort-component method in which gross in- and out-migration, and net immigration from abroad, are projected separately. The projections start, in effect, with estimates of State population by age and sex, for July 1, 1965. The estimates are then carried forward by 5-year time periods to each projection date on the basis of separate assumptions concerning future fertility, mortality, in-migration, out-migration, and net immigration.

A single set of projected survival rates was used for all States but alternative assumptions were employed for fertility and interstate migration. Two assumptions regarding future interstate migration were combined with two levels of fertility to derive four series of population projections. Two of the four series of available national fertility projections were adapted for this purpose.[69] State-to-national ratios of the general fertility rate were projected on the assumption that these ratios would reach unity in 50 years; i.e., in approximately 50 years, the fertility rates for all States would be equal to the national rate. Ratios for intermediate years were obtained by linear interpolation. These ratios were then applied to the previously computed national fertility rates to derive the fertility rates for States, which in turn were applied to projections of female population 15 to 44 years old for each State to derive the projected numbers of births. The projections of female population of childbearing age had been derived in a previous calculation by carrying forward the 1965 population using age-sex-specific survival rates and gross interstate migration rates. Births projected for each 5-year period for each State were then adjusted so that their sum over all States agreed with the total births in the previously calculated national projections.

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[66] See, for example: Sweden, Statistika Centralbyrån, *Befolkningsprojektion för kommunblocken till 1970, 1975, 1980 och 1985* (Population projections for cooperating communes to 1970, 1975, 1980, and 1985), Stockholm, 1969; idem, *Sveriges beräknade framtida folkmängd*, Part 2, *Underlag for lokala prognoser 1965, 1970 och 1975* (*Estimated future population of Sweden, Pt. 2, Basis for local projections, 1965, 1970, and 1975*), Statistiska Maddelanden B 1963 (4), Stockholm, p. 5; France, Institut de la statistique et des études économiques, "Perspectives d'évolution naturelle de la population par department" (Projections of natural increase of population by department), *Études Statistiques, Supplement Trimestriel du Bulletin Mensuel de Statistique* (Paris), No. 4, Oct.–Dec. 1957, pp. 63–64; and J. R. L. Schneider, "Local population projections in England and Wales," *Population Studies* (London), 10(1):98, July 1956.

[67] Illustrations of the various procedures noted here are given in: U.S. Bureau of the Census, *Current Population Reports*, Series P–25, No. 375, "Revised Projections of the Population of States, 1970 to 1985," October 3, 1967; Schneider, op. cit., pp. 105–111; France, Institut national de la statistique et des études économiques, "Perspectives d'évolution naturelle de la population par department," pp. 63–64; Bureau of the Census *Current Population Reports*, Series P–25, No. 160, "Illustrative Projections of the Population, by States: 1960, 1965, and 1970," August 9, 1957; and Sweden, Statistiska Centralbyrån, *Sveriges Beräknade Framtida Folkmängd*, Pt. 2.

[68] U.S. Bureau of the Census, *Current Population Reports*, Series P–25, No. 375, "Revised Projections of the Population of States, 1970 to 1985," Oct. 3, 1967; idem, *Current Population Reports*, Series P–25, No. 415, "Projections of the Population of Metropolitan Areas: 1975," Jan. 31, 1969; and Sweden, Statistika Centralbyrån, *Befolkningsprojektion för kommunblocken–till 1970, 1975, 1980 och 1985*.

[69] Series B and D in U.S. Bureau of the Census, *Current Population Reports*, Series P–25, No. 381.

The single set of survival rates employed were consistent with the "high" mortality series developed for and used in the national projections. The survival rates were applied to the initial population of each period to arrive at projections of survivors. The implied deaths for States were then adjusted to agree with the total number of deaths in the United States for age groups (by sex) developed in the national projections. No allowance was made for actual State differences in mortality since it was believed that they would have very little impact on the population projections.

For the projections of net migration, out-migration was first computed for each future period using rates observed in the census of 1960 for the 1955–60 base period, as adjusted to allow for observed net migration for the period 1960–65. The rates for 1955–60 represented the number of out-migrants from each State as a percent of the population of the State in 1955. (Accordingly, the projected rates were applied to the initial population of each 5-year projection period.) The projections of out-migrants for all States in each 5-year period were summed to obtain a national "pool" of migrants, which was then allocated to the States as in-migration, using the percentage distribution of the absolute number of in-migrants among the States observed during the 1955–60 base period. Under Series I, the rates of out-migration from States and the State in-migration distribution were held constant over time. Under Series II, the rates of out-migration from States were assumed to converge toward the national average rate, and the State in-migration distribution was assumed to converge toward the population distribution of the States. Under these assumptions, in about 50 years, the number of persons migrating from a State would be matched by an equal number moving into the State, resulting in zero net migration for each State.

Other approaches involving the separate projection of in- and out-migration for projecting regional population are based on the development of a model of interregional migration or a national demographic model incorporating regional changes. The possibility of developing a model of internal migration for use in projecting population has been reviewed by H. Ter Heide.[70] He concluded that, although there has been substantial progress in the development of a model which describes past migration, the problems of employing this model for purposes of population projections are almost insurmountable, if only because of the general lack of projections of the several independent variables on which the model depends. Ter Heide was concerned with models which incorporate economic, social, and psychological factors. On the other hand, Rogers has proceeded to develop "descriptive" models of interregional migration for use in projecting population; his models are less analytic and he has dealt so far only with the situation where the interregional migration rates are assumed to remain constant.[71]

Methods Taking Account of Economic Variables.—It is generally believed that internal movements are significantly affected by differential economic opportunities and that any drastic changes in the economic advantages of one area over another will have substantial impact on the future size of migration streams and even on the direction of net movement. Some research is being directed toward these relationships.[72] A number of methods have been developed which employ economic variables directly in the context of a ratio, component, or correlation method, or a combination of these methods. These methods take account of economic prospects quantitatively by basing the projections of population on projections of employment, per capita income, production, land use, or other economic variables. We consider the methods in two groups, those methods involving correlation with economic indicators and other methods using economic analysis.

Correlation with economic indicators.—Regression analysis may be employed to project the total population directly or to project the net migration component only (natural increase being projected separately in the latter procedure). An example of the use of this method is given by the projections of the population of States of the United States made at the Stanford Research Institute.[73] Projections of net migration for States were derived from a regression equation relating net migration and average per capita income. The fitted equation was as follows:

$$Y_c = 38.94255 + .402863X$$

in which Y_c stands for the net migration rate, 1950–60 (i.e., net migration for the decade as a percent of the 1950 population) and X stands for the percent change in per capita personal income for the decade expressed as a percent of the corresponding U.S. figure. Per capita income had been previously projected to 1970, and 1980 on the basis of the converging trend in per capita income observed in the 1950–60 decade. This procedure assumes that net migration for States is more closely correlated with per capita income than is total population change, that labor tends to move toward areas of higher per capita income, and that the systematic influence of income on migration flows will continue in the future.

The basic regression shows that a unit change in the per capita income of a State (in percentage form) causes a change of 0.4 in the percentage of net migration of that particular State. This factor was applied to the change in per capita income from 1960 to 1970 to derive "unadjusted" estimates of net migration in the 1960–70 decade. The estimates were then adjusted on the basis of the fact that the sum of the unadjusted figures over all States was far in excess of the expected total interstate migration for the United States computed separately. The adjustment procedure assumes different adjustment coefficients for different groups of similar States. An illustration of these steps is given for two States:

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[70] H. Ter Heide, "Migration Models and Their Significance for Population Forecasts," *Milbank Memorial Fund Quarterly*, 41(1):56–76, Jan. 1963.

[71] Andrei Rogers, "A Markovian Policy Model of Interregional Migration," *Regional Science Association Papers*, 17:205–224, 1966; and idem, "The Multiregional Matrix Growth Operator and the Stable Interregional Age Structure," *Demography*, 3(2):537–544, 1966.

[72] Ira S. Lowry, *Migration and Metropolitan Growth: Two Analytical Models*, San Francisco, Calif., Chandler Publishing Company, 1966.

[73] Pietro Balestra and W. Koteswara Rao, *Basic Economic Projections: United States Population, 1965–80*, Stanford Research Institute, Menlo Park, Calif., 1964, esp. pp. 37–44.

	Arkansas	*Ohio*
(1) Migration rate, 1950–60 (percent)......	−22.5	+5.7
(2) Percent change in per capita income, 1960–70 (independently projected)..	+7.2	−2.4
(3) Effect of income change = (2) × 0.4.....	+2.88	−.96
(4) Unadjusted migration rate, 1960–70 (percent) = (1) + (3)......................	−19.6	+4.7
(5) 1960 population (in thousands).........	1,786.3	9,706.4
(6) Unadjusted net migration, 1960–70 (in thousands) = (4) × (5)................	−350	+456
(7) Adjusted migration rate, 1960–70 (percent)[a]..	−19.6	+2.9
(8) Adjusted net migration, 1960–70 (in thousands) = (5) × (7)....................	−350	+281

[a] See source for explanation of adjustment in net migration rates.

Other methods using economic analysis.—Other methods of projecting the population of geographic subdivisions using economic analysis may involve an intensive study of the economic prospects for each area. One approach involves separate consideration of several main branches of the economy, proceeding from national to local employment in these branches, then to total employment in the area, and finally to total population. The local projections of employment in various branches of the economy may be made as a proportion of the corresponding national projections.

Another class of methods employs a limited type of component procedure which depends on prior projections of employment or labor force. In the simpler application, the projections of employment or labor force, and then net migration, are made directly for the population of all ages; in the more elaborate application, the projections of employment or labor force, and then net migration, are made by age groups. The method sequentially calculates employment or labor force, net migration of the labor force, net migration of the total population, and finally, the total population, combining the net migration with the expected population allowing for births and deaths. A specific example is provided by the population projections made by the Oregon State government for the State as a whole and its state economic areas, by age and sex, 1964.[74]

Although the method includes a number of adjustments to take care of special situations, the authors' "best judgement forecast" of net migration was derived basically as follows:

1. The current population was projected by age and sex as a closed population, that is, assuming zero net migration.

2. Projected age-sex-specific labor force participation rates were applied to these interim population "projections" to obtain the future labor force on the assumption of no further net migration.

3. An independent forecast of future employment by age was developed on the basis of a detailed analysis by industry classes.

4. To the forecast in step (3) an allowance for unemployment was added, to obtain an independent forecast of the future labor force.

5. The difference between the forecasts in step (4) and the projections in step (2) was taken to represent net in-migration or net out-migration of workers, depending on which was larger.

6. The net migration of the household population not in the labor force (including children and retired persons) was estimated by ratio inflations of the results in step (5), and special allowances were made for the net migration of such groups as the armed forces, college students, and inmates of institutions.

The adequacy of the method depends heavily on the adequacy of the projection of the total labor force, which is derived wholly by economic analysis. The method takes account of the mortality and fertility of persons who have migrated into or out the area only indirectly.

The more intensive procedures are difficult to apply since they require considerable data and involve the problem of demographic and economic interdependence. Careful study of the economy of an area, involving measurement of the future requirements for workers and of the degree to which these future requirements can be filled by the available population, on the one hand, and by net in-migration, on the other, is needed. This analysis would require some prior assumption as to the amount of net in-migration and prior projections of the size of the expected population. Initial assumptions would then have to be modified on the basis of what the initial projections imply as to labor deficits or surpluses. Even if the simplest method involving economic analysis is employed, the calculations become voluminous when age and sex detail is included and projections have to be prepared for a large number of areas. Under these circumstances, it becomes desirable or even necessary to carry out the work by electronic computer.

EVALUATION OF PROJECTIONS

Design of Evaluation Studies

As in the case of estimates, the evaluation of projections requires some standard by which to judge their quality. The possibilities of evaluating a set of projections are limited because current estimates or census counts for many years subsequent to the base date are needed. In the practical situation, this would permit evaluation of projections only after a long period of time has elapsed; by this date the methodology in current use may have changed and, hence, would not be encompassed by the evaluation. However, there is a broader issue. The concept of "accuracy" becomes less meaningful where several series of projections are offered as reasonable possibilities and, particularly, where none is designated as a "forecast." In this case would we judge the accuracy of the "medium" series, the one described as "most likely," each series individually, or some of them, recognizing that the projections were not offered as predictions?

When a particular projection has been designed as a forecast or prediction, it seems perfectly appropriate to measure its accuracy by a subsequent comparison with a census count or current estimate. We also believe that those projections which fit our definition of principal series (i.e., which claim to incorporate realistic assumptions and which are offered as reasonable possibilities of future population size) are also proper candidates for evaluation, especially the medium series in a set. One may reasonably compare each projection in a set of such projections with the population actually recorded to indicate how it deviates from the current figure. Such comparisons, expressed in terms of percent differences, have in fact, often been made.[75] They are also of value in selecting a series of projections for later use.

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[74] Oregon State Board of Census, *Population Bulletin*, Release No. P–10, "Population Forecast, State of Oregon and Economic Areas: 1960–85," by Richard B. Halley and Morton Paglin, Portland, Oreg., April 1964.

To achieve a limited evaluation of a set of projections, one may compare them with a revised set of projections made in subsequent years. Such a comparison suggests the probable direction of errors of the longer-term projections, as well as the actual error of the short-term figures which are compared with current estimates or revised short-term projections.

Attention may profitably be focused on the accuracy of the projection of net change and its components (births, deaths, and net migration) rather than on the population projection itself since these are the elements actually projected and since the analyst knew the initial population to begin with. The percentage error of the projected change will be very much larger than the percentage error in the projected population. Comparison of the actual components of change with the projected figures is particularly valuable since it provides insight into the reasonableness of the various assumptions and shows how the overall population projections may have benefited from compensating errors. A supplementary approach is to consider the errors in projections by age, identifying separately, if possible, the age group born since the base date of the projections. This comparison will not only indicate differences in the relative accuracy of projections of age groups, but will also indirectly provide some insight into the relative contribution of births and the other components to the total error.

Keyfitz has suggested further that, since the analyst ordinarily knows the current growth rate or other measures of current change, such as age-specific birth rates and death rates, relative success should be measured by the degree to which the analyst anticipates the deviation from the change resulting from the current rates of growth.[76] By that criterion the percentage errors will tend to be even larger for a given series of projections.

If the analyst's success in making projections for different dates and areas is being judged comparatively, an important standardizing factor is the length of the projection period. One would expect errors to be greater when the projection period is longer. The size of the area and its rate of growth would also be factors characterizing the area which might systematically affect the accuracy of the projections.

A possible further basis for evaluating projections is in terms of the range from the highest to the lowest series in a set of principal projections. The width of the range from the highest to the lowest projections depends on the regularity of past demographic trends, knowledge regarding past trends, ability to measure them accurately, and finally, the analyst's judgment of the likely course of future change. The range is, in a sense, a reflection of the analyst's confidence in the medium series of projections. As the range widens, he is indicating that he has less and less confidence that the medium figures will correspond to the actual figures. This suggests that, if the office producing the projections has successfully designed the range for several sets of projections made at different dates so as to reflect an equal, although unspecified, degree of confidence, the relative variation in the range is suggestive of the differences in the relative accuracy of various sets of projections. Certainly, from the user's point of view, given an assumption of equal probability from one set of projections to another that the "true" figure will fall in the range stated, the narrower the range the more useful the figures. The range may be measured as the difference between the highest and the lowest projections for a given date as a percent of the mean of the highest and lowest populations.

The real difficulty here is the assumption that one range covers the same confidence interval as another range. A few demographers have considered the problem of developing probabilistic measures of the accuracy of projections analogous to the sampling error of estimates derived from sample surveys. The issue has been examined most extensively by Muhsam and Sykes.[77] Muhsam believes that demographers should provide probability statements for each of their projections and that those who use forecasts should determine a quantitative loss function which would indicate the loss incurred when the forecasts used err by stated amounts.[78] Sykes has developed a model in which the variances of predictions are determined on the basis of the observed variability of vital rates. The model yields relatively high prediction variances for population projections, as confirmed by a numerical example with U.S. data.

National Projections

Several systematic studies of the accuracy of national projections have been made but these do not usually distinguish the method of projection, the components of error, or the length of the projection period.[79] The period-fertility variation of the component method, the method most widely used to project national population where vital statistics are available, has often been found to produce unsatisfactory results. Typically, the greatest source of error has been in the projections of births. Where several series have been projected, the range has usually been quite wide and yet has occasionally failed to encompass the actual population. The prospects for improving the accuracy of national population forecasts are not great although they may have considerable value as analytic tools.[80]

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[75] For illustrations see references given in footnotes 79 and 83.

[76] Nathan Keyfitz, "La proyección y la predicción en demografía: Un revisión del estado de este arte" (Projection and prediction in demography: A review of the state of the art), *Conferencia Regional Latinoamericana de Población, 1970*, proceedings of a conference sponsored by the International Union for the Scientific Study of Population and the Colegio de México, Mexico City, Aug. 17-22, 1970 (in press).

[77] H. V. Muhsam, "The Utilization of Alternative Population Forecasts in Planning," *Bulletin of the Research Council of Israel*, 5(2-3):133-146, March-June 1956; idem, "The Use of Cost Functions in Making Assumptions for Population Forecasts," in United Nations, *World Population Conference, 1965* (Belgrade), Vol. III, pp. 23-26; and Z. M. Sykes, "Some Stochastic Versions of the Matrix Model for Population Dynamics," *Journal of the American Statistical Association*, 64(325):111-130, March 1969.

[78] For example, the accuracy of projections for geographic subdivisions has been examined by Altouney in the general framework of the sources of uncertainties in planning water-resources projects. See Edward G. Altouney, *The Role of Uncertainties in the Economic Evaluation of Water-Resource Projects*, Institute in Engineering-Economic Systems, Stanford University, Stanford, Calif., Report EEP-7, August 1963.

[79] Joseph S. Davis, *The Population Upsurge in the United States*, War-Peace Pamphlets No. 12, Food Research Institute, Stanford University, December 1949; Harold F. Dorn, "Pitfalls in Population Forecasts and Projections," *Journal of the American Statistical Association*, 45(251):311-334, September 1950; Henry S. Shryock, Jr., "Accuracy of Population Projections for the United States," *Estadistica*, 12(45):587-598, December 1954; Robert J. Myers, "Comparison of Population Projections with Actual Data," in United Nations, *World Population Conference, 1954* (Rome), pp. 101-111; and Cézar A. Peláez, "The Degree of Success Achieved in the Population Projections for Latin America Made since 1950. Sources of Error. Data and Studies Needed in Order to Improve the Basis for Calculating Projections," in United Nations, *World Population Conference, 1965* (Belgrade), pp. 27-33. John V. Grauman, "Success and Failure in Population Forecasts of the 1950's: A General Appraisal," in United Nations, *World Population Conference, 1965* (Belgrade), pp. 10-14.

[80] John Hajnal, "The Prospects for Population Forecasts," *Journal of the American Statistical Association*, 50(270):309-322, June 1955.

The elaboration of the method has contributed at least to this function of projections.

The United Nations has systematically compared the projections for the regions and countries of the world published in 1966 with those published in 1958.[81] The differences for regions reflect reestimation of the present size of the population in each area and of current fertility and mortality levels, and a change in the assumptions used in the projections. The result of the new calculations for most of the world, in comparison with the earlier ones, is an initial acceleration of population growth and a subsequent deceleration. Judging the earlier projections on the basis of the current estimates for 1960 and the revised projections, the earlier medium projections for 1960 and 2000 were too low in some areas and too high in others by considerable percentages. The indicated percent "errors" in the projections for major world regions for various dates are shown in table 24-21. For example, the earlier medium projection for Africa in the year 2000 was 33 percent too low, and the medium projection for East Asia in 2000 was 44 percent too high, according to the revised projections.

The projections of U.S. population made during the 1930's and 1940's by the Scripps Foundation and the U.S. Bureau of

Table 24-21.—Comparison of United Nations Medium Projections for Major World Regions Published in 1966 and Corresponding Projections Published in 1957

[Percents represent the deviation of projections published in 1957 from the current estimates or revised projections as a percent of the current estimates or revised projections]

Country	Population, 1960 (millions)		Percent difference				
	1957	1966	1960	1970	1980	1990	2000
World	[1]2,910	2,998	-2.9	-3.1	-2.5	-0.9	+2.4
East Asia	796	794	+0.3	+6.2	+15.7	+27.5	+44.0
South Asia	827	865	-4.4	-8.5	-10.4	-10.3	-7.2
Europe	424	425	-0.2	+0.7	+3.3	+5.6	+7.8
U.S.S.R.	215	214	+0.5	+3.3	+6.8	+7.3	+7.4
Africa	235	273	-13.9	-19.7	-25.8	-30.2	-32.7
Northern America	197	199	-1.0	-0.9	-3.1	-7.5	-11.9
Latin America	206	212	-2.8	-6.4	-7.9	-8.4	-7.2
Oceania	16.3	15.7	+3.8	+3.7	-0.4	-4.8	-8.2

[1] Rounded to nearest 10 million.

Source: Adapted from United Nations, *World Population Prospects as Assessed in 1963*, Series A, Population Studies, No. 41, 1966, tables 4.3 and 4.4.

Table 24-22.—Comparison of Projections of the Components of Population Change With the Corresponding Current Estimates, for the United States: 1966 to 1969

[Population in thousands]

Projection series	Population		Population change, 1966 to 1969			
	July 1, 1969	July 1, 1966	Net change	Births	Deaths	Immigration
Population and population change:						
Current estimates	203,216	[1]196,907	6,309	10,676	5,697	1,331
Series A	205,311	[2]196,842	8,469	13,094	5,825	1,200
Series B	204,466	[2]196,842	7,624	12,229	5,804	1,200
Series C	203,635	[2]196,842	6,794	11,378	5,785	1,200
Series D	202,923	[2]196,842	6,082	10,649	5,767	1,200
Difference:[3]						
Amount:						
Series A	+2,095	-66	+2,161	+2,419	+127	-131
Series B	+1,250	-66	+1,315	+1,553	+107	-131
Series C	+419	-66	+485	+703	+87	-131
Series D	-293	-66	-227	-26	+70	-131
Percent:[4]						
Series A	+1.0	(Z)	+34.3	+22.7	+2.2	-9.8
Series B	+0.6	(Z)	+20.9	+14.5	+1.9	-9.8
Series C	+0.2	(Z)	+7.7	+6.6	+1.5	-9.8
Series D	-0.1	(Z)	-3.6	-0.2	+1.2	-9.8

Z Less than 0.05 percent.
[1] Revised estimate.
[2] Provisional estimate used as base of projection.
[3] Minus sign indicates that the estimate exceeds the projection.
[4] Estimate is the base of the percent.

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 441, "Estimates of the Population of the United States, by Age, Race, and Sex: July 1, 1967, to July 1, 1969," March 19, 1970, table G.

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[81] United Nations, *World Population Prospects as Assessed in 1963*, pp. 15-17.

the Census proved to be consistently too low, primarily because of understatement of future births. Although the range of the projections made during the 1950's and 1960's still encompassed the actual figures after several years, the projections were generally too low or too high, depending on whether the actual trend of fertility was up or down at the time the projections were being prepared.

A comparison of the U.S. projections for 1969, based on current estimates for 1966, with current estimates for 1969 illustrates the latter situation (table 24-22).[82] This comparison shows that the population increase in the 3-year period was overstated in Series A, B, and C by 34, 21, and 8 percent, respectively, and that the overstatement of births accounted principally for the errors in these series of projections. The overstatement of births was partly offset by an overstatement of deaths and an understatement of net immigration. The concentration of the error in the births is also reflected in the relatively large difference in the projections for children under 5 in Series A, B, and C, as compared with those for the population 5 and over (table 24-23).

Table 24-23.—**Comparison of Projections of the Population Under 5 Years Old and 5 Years Old and Over With the Corresponding Current Estimates, for the United States: July 1, 1969**

[Population in thousands]

Projection series and age (years)	Projection[1]	Current estimate[2]	Difference[3]	
			Amount	Percent[4]
Under 5 years:				
Series A	20,367	17,960	+2,407	+13.4
Series B	19,522	17,960	+1,562	+8.7
Series C	18,691	17,960	+731	+4.1
Series D	17,979	17,960	+19	+0.1
All series, 5 years and over	184,944	185,256	-312	-0.2
5 to 14	41,335	41,345	-10	(Z)
15 to 24	35,118	35,054	+65	+0.2
25 to 34	24,629	24,680	-51	-0.2
35 to 44	23,246	23,314	-68	-0.3
45 to 64	41,325	41,393	-69	-0.2
65 years and over	19,291	19,470	-179	-0.9

Z Less than 0.05 percent.

[1] Projections from U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 381, "Proiections of the Population of the United States, by Age, Sex, and Color to 1990, With Extensions of Population by Age and Sex to 2015," Dec. 18, 1967.

[2] Consistent with U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 428, "Estimates of the Population of the United States, by Age, Race, and Sex: July 1, 1969," Aug. 19, 1969.

[3] Minus sign indicates that the estimate is greater than the projection.

[4] Estimate is base of percent.

Source: U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 441, "Estimates of the Population of the United States, by Age, Race, and Sex: July 1, 1967 to July 1, 1969," Mar. 19, 1970, table H.

Geographic Subdivisions

Projections for states, provinces, localities, etc., are subject to much greater average error than those for whole countries (i.e., for a given length of projection period). The greater inaccuracy results partly from the added uncertainties of internal migration and partly from the fact that errors (or deviations in general) tend to vary inversely with population size.

Siegel's review in 1954 of the various U.S. tests of subnational projections concluded that no one method uniformly gave the best results and that in many cases a simple mathematical method was as accurate as a component method using age-specific rates.[83] The more elaborate methods, such as the cohort-component methods, would still be preferred for their analytic value, however.

He concluded further that the "error" rate tends to vary directly with the rate of population growth and with the length of the projection period. After 20 years no method any longer provided accurate forecasts. The longer the projection period the greater the likelihood of unforseen developments which can cause the actual population to fall outside the range projected. Similarly, population trends are less regular for small populations than large ones. Accordingly, projections for subnational areas should be carried out for fewer years than projections for countries as a whole. These findings and the practical need for consistency with current estimates suggest the need for frequent revision of the projections for geographic areas.

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[82] U.S. Bureau of the Census, *Current Population Reports*, Series P-25, No. 381, table B.

[83] Jacob S. Siegel, "Some Aspects of the Methodology of Population Forecasts for Geographic Subdivisions of Countries," in United Nations, *World Population Conference, 1954* (Rome). See also Helen R. White, "Empirical Study of the Accuracy of Selected Methods of Projecting State Populations" *Journal of the American Statistical Association*, 49(267):480–498, September 1954; Jacob S. Siegel, "Forecasting the Population of Small Areas," *Land Economics*, 29(1):72–87, February 1953; and Robert C. Schmitt and Albert H. Crosetti, "Accuracy of the Ratio Method for Forecasting City Population," *Land Economics*, 27(4):346–348, November 1951.

Editor's note: This material is taken from U.S. Department of Commerce, Bureau of the Census, *Illustrative Projections of World Populations to the 21st Century*, Washington: Government Printing Office, 1979, pp. 13–15.

PROJECTION METHODS

Base-Year Data

The projections in this report begin from a single estimate of a populations's size and age distribution for a specific "base year." The preferred base year in this report is 1975; a different base year was established only when data were insufficient for an acceptable single estimate of population size and age distribution for 1975.

The base year for projections for each of the more developed regions and countries shown in this report is 1975. In the case of these countries, either census data were available for 1975 or an estimate for 1975 was made on the basis of census data for a recent year and on the availability of reliable statistics on births, deaths, and net migration. The base year for the "remainders" of less developed regions is also 1975, although the quality of the available data and resulting estimates for these areas is lower than for the more developed areas. The United Nations medium variant projections of the population by age and sex for 1975, with some adjustments where needed, served as the base year population for remainders of regions.

Base years for the less developed countries shown in this report vary according to the year for which the most reliable data are available. Only for three of the less developed countries, namely Egypt, Nigeria, and Pakistan, is the base year 1975. Base years for the other nine less developed countries for which projections are shown in this report are: Bangladesh, 1974; Brazil, 1970; People's Republic of China, 1953; India, 1971; Indonesia, 1971; Mexico, 1970; Philippines, 1970; South Korea, 1970; and Thailand, 1970. Population estimates for these countries as of 1975 were subsequently made based on past trends in fertility, mortality, and net international migration.

Base-year fertility and mortality rates. As part of its continuing program in the collection and evaluation of international demographic data, the Census Bureau had previously prepared estimates of base-year fertility levels for most of the less developed countries in this report. These estimates consisted of a schedule of age-specific fertility rates and the corresponding total fertility rate for each country, which then served as the base-year fertility levels. For areas not specifically studied, U.N. fertility levels were used, except for Colombia, Turkey, and Iran, where new data indicated that the actual 1975 fertility levels were significantly different from the projected U.N. levels.

Base-year fertility levels for the more developed countries were adapted from those used by the individual countries in making national projections, with some adjustment to bring them up to the base year of 1975.

Levels of base-year mortality were estimated from the same sources as base-year fertility.

Assumptions About the Future

In order to project the future size and age distribution of populations using the components method, assumptions must be made about the future course of each of the components of population growth. Thus, one must specify whether fertility levels will rise or fall, and to what extent; whether or not people will live longer on the average; and, for projections of individual countries and regions, what will be the amount of net migration.

The illustrative population projections presented here are based on the general assumption that there will be no major catastrophes, widespread epidemics, or social, political, or economic upheavals in the future. While no component of demographic change can be predicted exactly, demographic history in recent decades has shown that changes in mortality and net international migration are likely to have less impact than changes in fertility on the size and composition of future population. As a result, the larger the proportion of a projected population born after the base date, the more uncertainty there is in the projected population.

The population projections shown in this report are "correct" in the sense that they accurately illustrate the population growth that would result from a given base year population estimate subjected to varying levels of vital rates. Of course, population projections will be valid only to the extent that they are derived both from reliable estimates of base year populations and from accurate assumptions about the future course of those demographic factors which affect population growth. Recent demographic history in both more and less developed countries has shown that very rapid changes in vital rates, especially fertility, can occur in time periods even shorter than the projection period chosen in this report.

Migration. In order to simplify the problem of making population projections for individual countries and regions, the assumption has been made that there will be no migration from one country to another between 1975 and the year 2000. This assumption certainly introduces an element of error into any population projection. However, it seems likely that net migration will be the least important factor influencing population growth, as international migration within large geographical areas has superseded earlier overseas migration between Europe and the Americas.[11] In support of this contention, the data below show that the overall effect of net migration on population growth in Europe for the 1950-70 period was negligible (a loss of only 4 percent), although considerable variation in the importance of net migration on population growth can be found in the component regions.

Estimates of Net Migration in Europe: 1950 to 1970

Region	Net migrants (thousands)	Ratio of net migration to natural increase (percent)
Europe[1]	-3,028	-4
Western Europe	+8,748	+51
Southern Europe	-7,301	-29
Eastern Europe	-3,777	-21
Northern Europe	-698	-8

[1] The regional assignment of countries differs from that shown elsewhere in this report.

Source: United Nations Secretariat, "International Migration Trends, 1950-1970," The Population Debate: Dimensions and Perspectives, Papers of the World Population Conference, Bucharest, 1974, Vol. I (United Nations publication, Sales No. E/F/S.75.XIII.4), p. 247.

With respect to individual countries, the assumption of no further migration can adversely affect the quality of the population projection, especially where the rate of natural increase is very low. For example, although the level of net migration into the United States has been between 300,000 and 400,000 persons a year for the past several decades, substantial declines in fertility have increased the net migration component of population growth from 10 to 15 percent in the 1950's to 20 to 25 percent during the 1970's.[12]

Fertility. The general conceptual framework which underlies the fertility assumptions made in these projections is as follows:

1. The less developed countries will continue to make moderate progress in social and economic development during the 1975-2000 period.
2. Fertility will decline as less developed countries progress in social and economic development. In the long run, the fertility level is expected to decline more or less continuously, though with some temporary plateaus.
3. Almost all countries, which do not already do so, will make family-planning services available to an appreciable portion of the population during the 1975-2000 period, and those countries with family-planning programs now in operation will extend coverage, particularly in rural areas.
4. Knowledge and methods of family limitation will become better known and will be more widely used among populations that wish to reduce fertility. Expansion of family-limitation practices will expedite the process of fertility decline, and in countries where rapid social and economic progress and strong desires for smaller families coincide, fertility decline will be very rapid.

Three projection series for fertility were made for each individual country or geographical area. In setting the high, medium, and low levels of fertility in the year 2000, some general guidelines were followed:

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[11] See United Nations, "The World Population Situation in 1970," **Population Studies**, No. 49 (New York: United Nations Department of Economic and Social Affairs, ST/SOA/Series A/49, 1971).

[12] In the official Census Bureau medium projection of the population of the United States, some 12 million more people are expected by the year 2000 if a net migration assumption is included in the population projection than if no migration is assumed. See U.S. Bureau of the Census, **Current Population Reports**, Series P-25, No. 704, "Projections of the Population of the United States: 1977 to 2050" (Washington, D.C.: U.S. Government Printing Office, 1977).

1. The higher the level of fertility at the base date, the wider the range of assumed fertility levels in the year 2000.
2. The greater the uncertainty about the current fertility levels and current trends, the greater the range of assumed fertility levels in the year 2000.

The three fertility projection series in this report did not use any mathematical models of fertility change; instead, the assumptions were made on a judgmental basis by demographers who have worked with the demographic and related socioeconomic data for the individual countries for a number of years. For the less developed countries for which individual projections were made, the demographers set the target fertility decline by taking into consideration the following factors:

1. Current levels and recent trends in fertility;
2. current levels and recent trends in social and economic development;
3. current status and past performance of family planning and public health programs;
4. government policy on population related matters;
5. recent fertility trends in countries with similar cultural, social, and economic conditions and prospects;
6. expressed "desired family size" in the population;
7. fertility assumptions made by international agencies, such as the United Nations and the World Bank.

In setting the target fertility levels and projection paths, special consideration was given to fertility assumptions made in population projections prepared by national agencies and universities in the countries under consideration. The rationale was the belief that demographers in the individual countries may have a unique understanding of what are reasonable fertility levels to expect in the future for their own country. Such national projections for less developed countries were available and were considered in making assumptions for Brazil, Indonesia, Pakistan, the Philippines, South Korea, and Thailand. With respect to the more developed countries, almost every country has made its own official national projection; with slight modifications in some instances, these official projections were used in this report.

After the fertility levels for the intermediate years were determined for each projection series, the age patterns of fertility were selected for the initial projection year and the year 2000. Age-specific fertility rates for the intervening years were then chosen to reflect the level of fertility for those years.

Mortality. One mortality assumption was used for all three projection series, except for the People's Republic of China.[13] Mortality estimates for the base year of the projections and for the projection period were estimated from a variety of sources, including registered deaths by age and sex, often adjusted for underregistration; survey or census data on deaths by age and sex during the preceding year; or by analyzing age distributions of the population at one or more points in time and applying accepted demographic techniques, e.g., stable population analysis or model life tables to generate an appropriate life table. In a few countries, such as Nigeria, where no reliable information is available, "guesstimates" as to the level of mortality and the appropriate model life table pattern were made, with consideration given to estimates that had been previously made by other agencies and research centers.

Projections of mortality from the base year were generally done in one of two ways: Either a target life expectancy at birth (and a corresponding life table) was chosen for the year 2000 and life expectancies for the years between 1975 and 2000 were graphically interpolated; or the pattern and degree of change in mortality from year to year was assumed with the eventual life expectancy in the year 2000 resulting from the projection process. Whether target life expectancies were initially chosen or whether the trend was initially chosen, consideration was always given to the trends and levels shown in already existing national projections, and the mortality trends that have occurred in similar countries. Target life expectancies for the year 2000 were sometimes chosen to be the same as those already achieved in "leading" countries, or previously assumed in projections made by other agencies and organizations.

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[13] Since the People's Republic of China is such a large component of (1) the World, (2) less developed countries, and (3) Asia and Oceania, high and low mortality series differ from the medium series for these three areas as well.

Editor's note: This material is taken from U.S. Department of Commerce, Bureau of the Census, *Illustrative Projections of World Populations to the 21st Century*, Washington: Government Printing Office, 1979, Appendix B, pp. 95–116.

Sources of Base-Year Data and Projection Assumptions

PEOPLE'S REPUBLIC OF CHINA

Base Data

Base date: January 1, 1953

Population. The population estimates and projections for the People's Republic of China were made by the staff of the Foreign Demographic Analysis Division, U.S. Bureau of the Census (1976). The base population data were derived from the June 30, 1953 census, and are based on a model age-sex distribution that was designed to reflect the probable demographic history of China for the preceding three centuries.

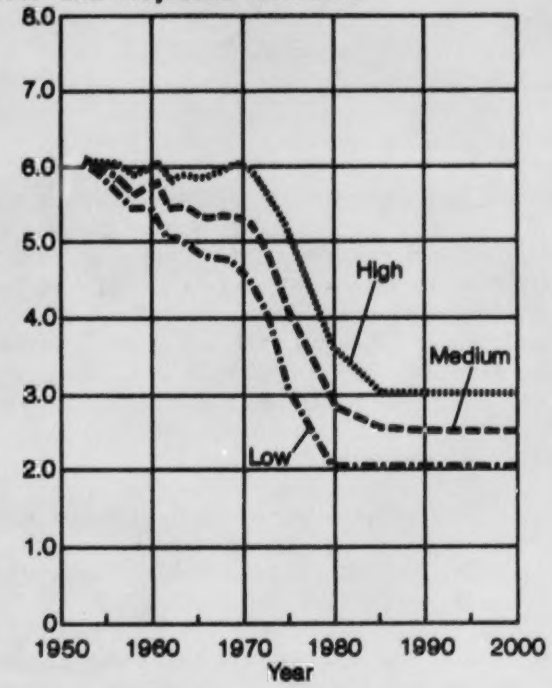
Fertility level. Based on a model reconstruction of the population of China, the crude birth rate was estimated to be 45 per 1,000 in 1953. This level of the crude birth rate corresponds to an estimated total fertility rate of 6.1 children per woman.

Mortality level. A crude death rate of 22.5 per 1,000 was estimated for China in 1953. Model life tables were used to derive an expectation of life at birth of about 40 years for males and 43 years for females.

Projection Assumptions

Fertility. In all series, the total fertility rate was estimated to have declined by the year 1975, with the most rapid annual declines occurring after 1969. The total fertility rate was assumed to have declined by 1975 to 5.2 in the high series, 4.1 in the medium series, and to 3.1 in the low series. Further declines are projected to occur between 1975 and 1985 by about 40 percent in each series resulting in a total fertility rate by 1985 of 3.1 in the high series, 2.6 in the medium series, and 2.1 in the low series. These rates are then assumed to remain stable during the remainder of the projection period.

FIGURE B-1.
Total Fertility Rates for the People's Republic of China: Estimated 1953 and Projected 1953-2000



Mortality. In all series, life expectancy at birth was assumed to have fluctuated erratically between 1953 and 1961. In the high-projection series, life expectancy was assumed to have increased by 1961 to 42 years for males and 45 years for females. A steady rise was projected for the remainder of the projection period, reaching 60 and 64 years, respectively, for males and females by the year 2000. In the medium-projection series, life expectancy at birth was assumed to have declined by 1961 for both males and females to 38 and 41 years, respectively. Between 1961 and 2000, however, an increase of almost 75 percent has been projected which results in an expectation of life at birth of 65 years for males and 69 years for females by the year 2000. In the low-series projection, life expectancy falls between 1953 and 1961 to 34 and 37 years, respectively, for males and females. Life expectancy at birth then doubles by the year 2000 to 70 years for males and 74 years for females.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Foreign Demographic Analysis Division, U.S. Bureau of the Census. 1976. Population Estimates and Projections for the People's Republic of China. Computer printouts, unpublished.

U.S.S.R.

Base Data

Base date: January 1, 1975

Population. The population estimates and projections for the U.S.S.R. were prepared by the staff of the Foreign Demographic Analysis Division, U.S. Bureau of the Census (1977). The base population data were derived from the age-sex distribution of the January 15, 1970 census and were subsequently adjusted on the basis of the single year of age distribution for the U.S.S.R. (U.S. Bureau of the Census, 1973). Annual data on births, deaths, and net migration were used to advance the population to the base date (Central Statistical Administration).

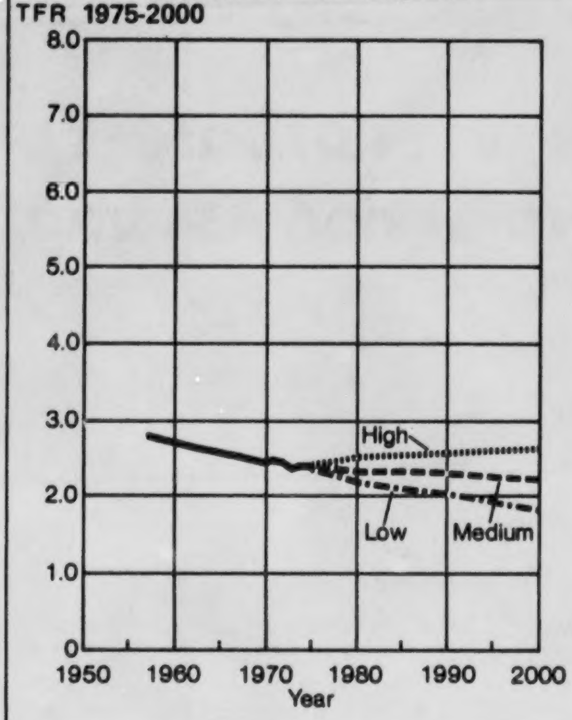
Fertility level. Age-specific fertility rates for 1975 were from official government sources (Central Statistical Administration, 1976, No. 11, p. 86). The total fertility rate for 1975 was estimated to be 2.4 children per woman.

Mortality level. Life table values for 1975 were derived from 1973-74 estimates of mortality rates (Central Statistical Administration, 1975, No. 12, p. 84). Life expectancy at birth in 1975 was estimated to be 63.1 years for males and 73.8 years for females.

Projection Assumptions

Fertility. The total fertility rate of 2.4 in 1975 was assumed to have increased by the year 2000 to 2.7 in the high series, and to have decreased to 2.3 in the medium series and to 1.9 in the low series.

FIGURE B-2.
Total Fertility Rates for U.S.S.R.: Estimated 1957-75 and Projected 1975-2000



Mortality. In all series, life expectancy is assumed to increase gradually during the projection period by 2.5 years, resulting in a life expectancy at birth in the year 2000 of 65.6 years for males and 76.3 years for females.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Central Statistical Administration. Various dates. Vestnik Statistiki. U.S.S.R. Council of Ministers.

Foreign Demographic Analysis Division, U.S. Bureau of the Census. 1977. Estimates and Projections for the U.S.S.R. Computer printouts, unpublished.

U.S. Bureau of the Census. 1973. International Population Reports, "Estimates and Projections of the Population of the U.S.S.R., by Age and Sex, 1950-2000," Series P-91, No. 23.

INDIA

Base Data

Base date: July 1, 1971

Population. The base population data were derived from the April 1, 1971 census adjusted for 2.7 percent net underenumeration. The 1961 and 1971 population censuses were adjusted by a cohort analysis, accepting estimated levels of mortality and fertility during the intercensal period. Assumptions were made concerning trends in the sex ratios for each cohort during the 10-year period, by age and sex, from the 1971 Post Enumeration Check (Registrar General and Census Commissioner, 1975, pp. 33-36).

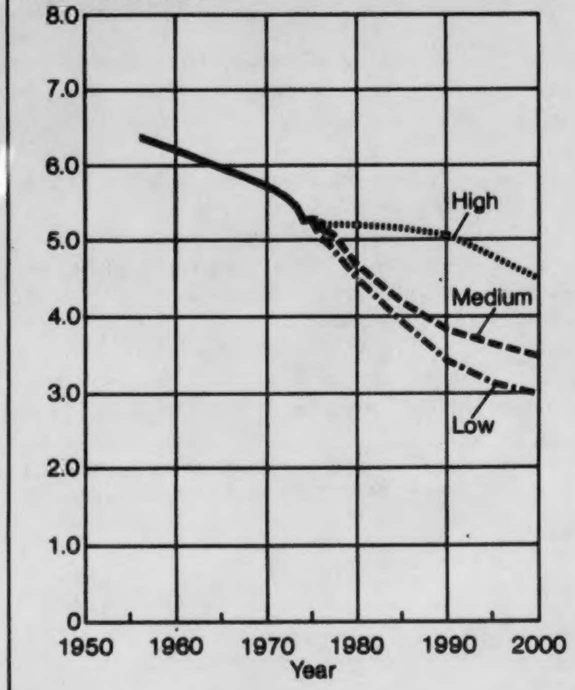
Fertility level. The total fertility rate for 1971 is a weighted average of 1969 urban and rural age-specific fertility rates derived from the Sample Registration System (Office of the Registrar General, 1972, pp. 7 and 32). The combined rates were inflated to achieve an estimated crude birth rate of 39 per 1,000 for 1971. The estimated crude birth rate was based on a reported All-India rate from the Sample Registration System (Registrar General, 1976, p. 2) and subsequently inflated by 5 percent (see Registrar General, 1974, p. 7, and Registrar General and Census Commissioner, 1974, p. 10).

Mortality level. Empirical life tables for 1969 were derived from age-sex specific death rates from the Sample Registration System (Office of the Registrar General, 1972, pp. 58-62 and 72-77). These rates were graphically smoothed and adjusted using as a guide data from the National Sample Survey (Cabinet Secretariat, no date, p. 16). Life expectancies at birth by sex for 1971 were derived by estimating probable improvements in the life expectancies since 1969 and by assuming that the age pattern of mortality was that implied by the Coale-Demeny south region model life tables at equivalent levels of life expectancies (Coale and Demeny, 1966).

Projection Assumptions

Fertility. The total fertility rate of 5.7 in 1971 was estimated to have declined by about 7 percent to 5.3 in 1975 in all series, after considering the trend in crude birth rates from 1971 to 1975 from the Sample Registration System (Registrar General, 1976, p. 2, and Chari, 1977, p. 4). By the year 2000, the rates were assumed to have declined to 4.5 in the high series, 3.5 in the medium series, and 3.0 in the low series. In the medium series, the fertility rate for the year 2000 was assumed to approximate the "desired family size" (between 3 and 4 children) in India as shown by data from area and national surveys conducted around 1970 (Rao and Mullick, 1974, pp. 325 and 342, and Nair, 1974, pp. 345-355). The rate for the low series was assumed to be 0.5 below the level of the medium series. Both the medium and the low series have approximately the same rates in the year 2000 as those for the period 1995-2000 in the United Nations medium and low variant projections, respectively (United Nations, 1975, p. 125). The high series was projected to reflect a pessimistic view of the future direction of the Indian family planning program that has prevailed since the March 1977 elections and the advent of the new government in India.

FIGURE B-3.
Total Fertility Rates for India: Estimated 1956-75 and Projected 1975-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 51.5 years to 62.7 years for males and from 50.6 years to 64.5 years for females between 1975 and 2000. The life expectancies at birth for the year 2000 were estimated considering past trends in mortality, mortality in other countries of the region, United Nations projections, and expected improvements in the social, economic, and health sectors of the country.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Cabinet Secretariat. no date. **The National Sample Survey, Fourteenth Round, July 1958 – June 1959. Fertility and Mortality Rates in Rural India.** Report No. 89. New Delhi.

Chari, R. B. 1977. "Vital Statistics Systems in India." Paper prepared for Conference on Vital Statistics in Asia, May 9-13, Manila.

Coale, Ansley J. and Paul Demeny. 1966. **Regional Model Life Tables and Stable Populations.** Princeton University. Princeton.

Nair, P. S. 1974. "Desired Family Size: Correlates and Reliability of Responses." **Demography India.** Vol. III, No. 2. New Delhi.

Office of the Registrar General. 1972. **Measures of Fertility and Mortality in India.** SRS Analytical Series. No. 2. New Delhi.

Rao, Kamala Gopal, and Saroj Mullick. 1974. **Studies in Family Planning: India.** Abhinov Publications. New Delhi.

Registrar General. 1974. **Age and Life Tables (One Percent Sample).** Series 1 - India. Miscellaneous Studies. Paper 2. New Delhi.

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Registrar General and Census Commissioner. 1974. **The Population of India.** National Population Monograph in the CICRED Series. New Delhi.

__________. 1975. **Census of India 1971. General Population Tables.** Series 1 - India. Part II-A (i). New Delhi.

United Nations. 1975. **Selected World Demographic Indicators by Countries, 1950-2000.** ESA/P/WP.55. New York.

INDONESIA

Base Data

Base date: July 1, 1971

Population. The base population data were derived from the September 24, 1971 census adjusted for 3.8 percent net underenumeration. The 1961 and 1971 population censuses were adjusted using a cohort analysis, by age and sex, accepting estimated levels of mortality and fertility during the intercensal period and assuming certain trends of the sex ratios in each age cohort during the 10-year period.

Fertility level. The total fertility rate for 1971 was estimated by considering final and preliminary fertility estimates from the 1973 Fertility-Mortality Survey (University of Indonesia Demographic Institute, 1974-75 and 1975), estimates derived by the own-children method using data from the 1971 census (Indonesia Central Bureau of Statistics, 1976, table 1.1), preliminary data from Phase I of the 1976 Intercensal Population Survey (East-West Population Institute, 1977), and preliminary results from Phase III (World Fertility Survey) of the 1976 Intercensal Population Survey for Java and Bali. An average of the 1965-70 rate from the 1973 survey and the 1967-70 rate estimated from the 1971 census own-children data was assumed to apply to 1971. This level was supported by the preliminary data available from Phase III of the 1976 Intercensal Population Survey.

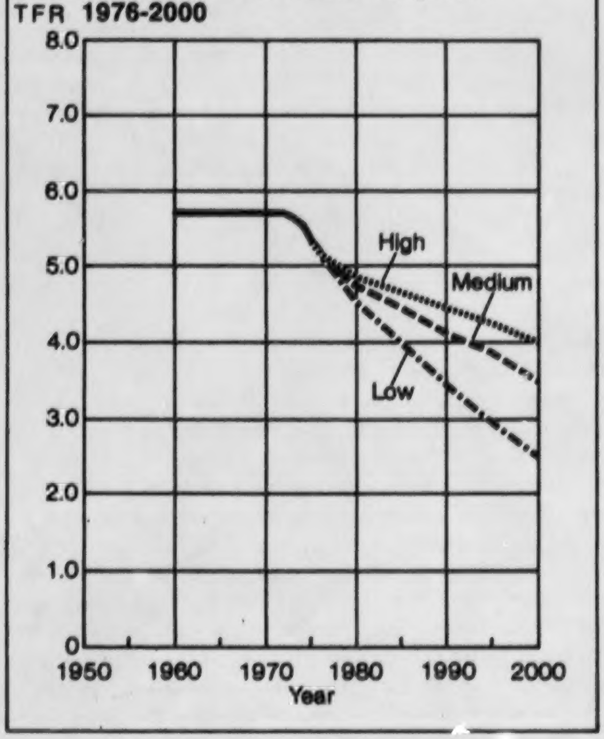
The age pattern of fertility for 1971 was accepted from the 1965-70 age-specific fertility rates from the 1973 Fertility-Mortality Survey.

Mortality level. Empirical life tables for 1971 were derived by applying the census survival technique to 1961 and 1971 census data (U.S. Bureau of the Census, 1975, pp. 9 and 10).

Projection Assumptions

Fertility. The total fertility rate of 5.7 in 1971 was assumed to have declined by 10 percent to 5.1 in 1976, considering preliminary results from Phase III of the 1976 Intercensal Population Survey and the change in the number of new acceptors in the family-planning program between 1971 and 1976. The rate of 5.1 in 1976 was assumed to have declined by the year 2000 to 4.0 in the high series, 3.5 in the medium series, and 2.5 in the low series. The high and medium levels were chosen after considering past trends in fertility and assumptions made by the East-West Population Institute (1977), the United Nations (1975), and the University of Indonesia Demographic Institute (1973, p. 69) for their population projections. The low level was chosen to yield a crude birth rate in 2000 that is approximately 50 percent of the 1971 crude birth rate which represents the goal of the Indonesian National Family Planning Coordinating Board.

FIGURE B-4.
Total Fertility Rates for Indonesia: Estimated 1960-76 and Projected 1976-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 40 years to 56 years for males and from 43 years to 60 years for females between 1971 and 2001. After considering past trends in mortality, mortality trends in other countries of the region, and projections made by the United Nations (1975), the East-West Population Institute (1977), and the University of Indonesia Demographic

Institute (1973, p. 68), the assumptions made by the University of Indonesia for 2001 were accepted and subsequently interpolated for the year 2000.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

East-West Population Institute. 1977. Personal communication.

Indonesia Central Bureau of Statistics. 1976. **Estimates of Fertility and Mortality in Indonesia Based on the 1971 Population Census**, by Lee-Jay Cho, Sam Suharto, Geoffrey McNicoll, and S. G. Made Mamas. SP 76-L02. Jakarta.

United Nations. 1975. **Selected World Demographic Indicators by Countries, 1950-2000.** ESA/P/WP.55. New York.

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University of Indonesia Demographic Institute. 1973. **The Population of Indonesia.** National Population Monograph in the CICRED Series. Jakarta.

__________. 1974-75. **Indonesian Fertility-Mortality Survey 1973, Preliminary Report (Various provinces).** Jakarta.

__________. 1975. **Levels and Trends in Fertility and Childhood Mortality in Indonesia,** by Peter F. McDonald, Mohammed Yasin, and Gavin W. Jones. Monograph Series No. 1. Jakarta.

BANGLADESH

Base Data

Base date: July 1, 1974

Population. The base population data are from the final March 1, 1974 census figure, adjusted for the 6.4 percent net underenumeration found in the Post-Enumeration Check (Bangladesh and United Kingdom, 1977, p. 3). The total population figure was then projected forward to July 1, 1974, at a growth rate of 2.67 percent, and an appropriate age-sex distribution was derived from the adjusted 1974 census (Bangladesh and United Kingdom, 1977, p. 3).

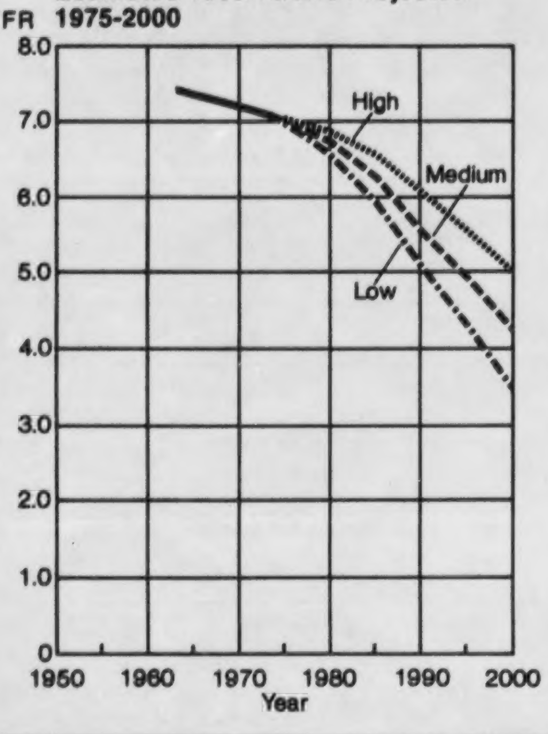
Fertility level. Age-specific fertility rates for 1973 are based on data from the 1974 Bangladesh Retrospective Survey of Fertility and Mortality (BRSFM) for births occurring 12 months prior to the survey (Bangladesh and United Kingdom, 1977, p. 4). The unadjusted age-specific fertility rates were then used as a guide in selecting a model fertility pattern rather than using them directly to obtain the age-specific fertility pattern. (Bangladesh and United Kingdom, 1977, pp. 160-163). The 1973 rate was then projected to the base year date of 1974 (see following section on projection assumptions).

Mortality level. A life table for the 5-year period preceding the 1974 census was derived based on the application of the Brass and Brass-Hill techniques to data on children ever born, children surviving, orphanhood, and widowhood as reported in the 1974 BRSFM (Bangladesh and United Kingdom, 1977, pp. 88-92). The life-table values were assumed to apply to 1971, the midpoint of the 5-year period. The 1971 expectancies were then projected to the base-year date of 1974 (see following section on projection assumptions).

Projection Assumptions

Fertility. The total fertility rate of 7.1 in 1973 was assumed to have declined to 7.0 for all series by 1975. A further decline was projected for the year 2000 to 5.0 in the high series, 4.3 in the medium series, and 3.5 in the low series. The same range of projected rates was assumed for both Bangladesh and Pakistan. Since Bangladesh is currently at a lower developmental stage than Pakistan, there is a tendency to assume a slower fertility decline in Bangladesh. However, because of the immense population pressure[1] and the emphasis on sterilization as a means of birth control in Bangladesh, it was assumed that fertility decline would occur at approximately the same pace for both countries.

FIGURE B-5.
Total Fertility Rates for Bangladesh: Estimated 1963-75 and Projected 1975-2000



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[1] Bangladesh has approximately 8 million more people than Pakistan and less than one-fifth the land area.

Mortality. In all series, life expectancy at birth was assumed to increase from 45.8 years to 53.5 years for males and from 46.6 years to 54.5 years for females between 1971 and 2000. The life expectancies at birth for the year 2000 were estimated considering past trends in mortality, mortality trends in other countries of the region, United Nations mortality projections, and expected improvements in the social, economic, and health sectors of the country. The life expectancy of both sexes in 2000 is at the same level as the United Nations medium variant of 54 years.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Bangladesh, Census Commission and United Kingdom, Ministry of Overseas Development. 1977. **Report on the 1974 Bangladesh Retrospective Survey of Fertility and Mortality.** London.

United Nations. 1965. **Population Bulletin of the United Nations, No. 7 - 1963: With Special Reference to Conditions and Trends of Fertility in the World.** New York.

PAKISTAN

Base Data

Base date: July 1, 1972

Population. The base population data were derived from the final September 16, 1972 census figures (Census and Registration Organization) and a July 1, 1972 population was estimated, assuming an annual growth rate of 3.0 percent. An age-sex distribution was then derived by applying the percentage distribution of an interpolated 1972 United Nations medium-variant population. Although the reported age-sex distribution from the 1972 census was available, it was not used since it appeared to be unrealistic.

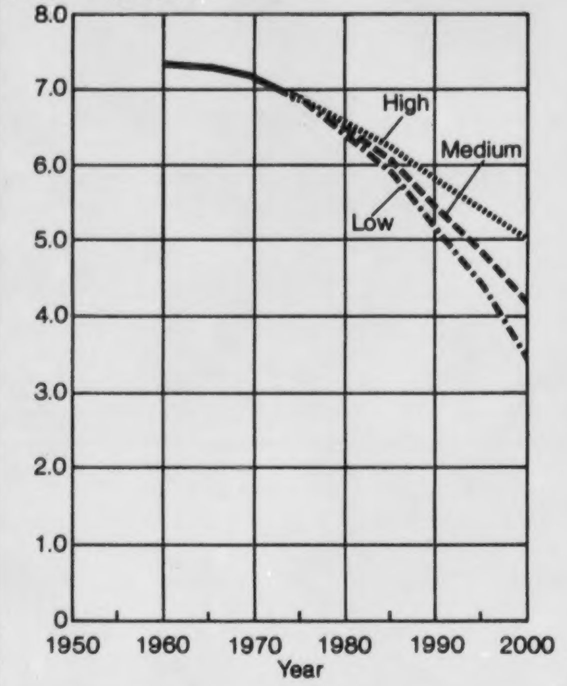
Fertility level. Age-specific fertility rates for 1972 were based on 1974-75 rates from the Pakistan Fertility Survey which was conducted in 1975 (Population Planning Council of Pakistan, 1976, table 3.7 and appendix tables 1.1, 1.3, and 2.2.1 (a)). The rates were adjusted using the Brass technique which resulted in a total fertility rate of 6.93. These rates were graphically extrapolated back to 1972, the date of the benchmark population.

Mortality level. The mortality level was based on a life table constructed using data from the 1962-65 Population Growth Estimation (PGE) Experiment (Technical Sub-Committee for Planning Division, 1968).

Projection Assumptions

Fertility. The total fertility rate of 7.0 in 1972 was assumed to have declined to 6.9 by 1975. By the year 2000, the rates were assumed to have declined to 5.0 in the high series, 4.3 in the medium series, and 3.5 in the low series. In the medium series, the fertility rate for the year 2000 is approximately at the level of the United Nations medium variant. The low-series projection for the year 2000 is the same as the India medium-series projection. The high series projected rate of 5.0 for the year 2000 was chosen so that the medium series projected rates would be equidistant between the high and low series.

FIGURE B-6.
Total Fertility Rates for Pakistan: Estimated 1960-75 and Projected 1975-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 47.8 years to 62.5 years for males and from 45.1 years to 64.3 years for females between 1964 and 2000. The life expectancies at birth for the year 2000 were estimated considering mortality trends in other countries of the region, United Nations mortality projections, and expected improvements in the social, economic, and health sectors of the country. The life expectancy of both sexes in 2000 is approximately at the same level as the United Nations medium variant, 63.0 years.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Census and Registration Organization. 1977. Unpublished computer printouts.

Population Planning Council of Pakistan. 1976. **Pakistan Fertility Survey, World Fertility Survey, First Report.** Lahore.

Technical Sub-Committee for Planning Division. 1968. "Population Projections for Pakistan." Karachi.

PHILIPPINES

Base Data

Base date: July 1, 1970

Population. The base population data were derived from the May 6, 1970 census adjusted for an estimated 1.9 percent net underenumeration, and projected to the midyear by considering estimated levels of fertility, mortality and migration, and the 1960-70 and 1970-75 intercensal growth rates. The 1970 census was adjusted by distributing the total population figures by age and sex based on a 5-percent sample of census returns (Bureau of Census and Statistics, 1972). The resulting age-sex distribution was smoothed for age misreporting and the population under 10 years of age was estimated based on assumed birth rates and survival ratios for the 10 years preceding the census.

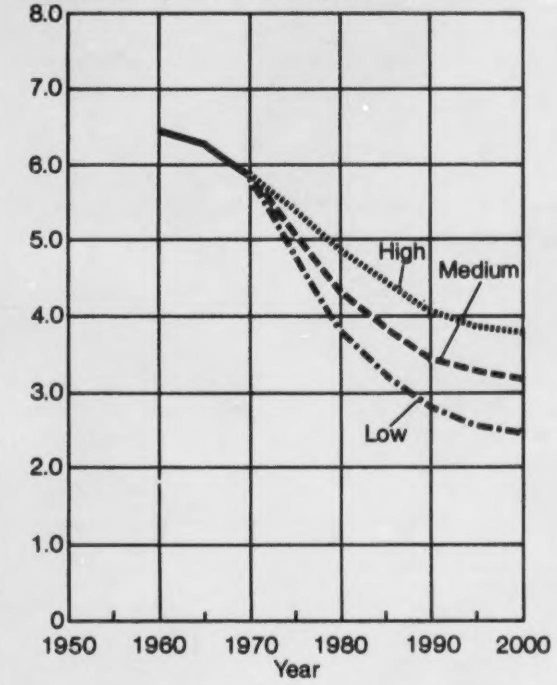
Fertility level. The age-specific fertility rates for the 1968-72 period are from the 1973 National Demographic Survey (Concepcion, 1974, table 1) and were accepted as accurately representing the level and pattern of fertility in 1970.

Mortality level. The 1970 male and female life tables used were those estimated by Engracia (1974, table 1).

Projection Assumptions

Fertility. The total fertility rate of 5.9 in 1970 was assumed to have declined by the year 1975 to 5.4 in the high series, 5.1 in the medium series, and 4.8 in the low series. In the high series, the rate for the year 1975 was based on the average of the 1970-75 and 1975-80 period rates from the National Census and Statistics Office (1974a, table 8) medium-projection series. In the medium series, the rate for the year 1975 was based on a rate necessary to be consistent with the 1975 preliminary census figure (inflated for 1.9 percent underenumeration), given assumed trends in mortality and migration between 1970 and 1975. In the low series, the rate for 1975 was based on an extrapolation of the average annual trend found in the Philippine Area Fertility Study between 1968 and 1974 (Flieger, 1977). The total fertility rates for 1975 were assumed to have declined further by the year 2000 to 3.8 in the high series, 3.2 in the medium series, and 2.5 in the low series. In the high and low series, the rates for the year 2000 were based on an extrapolation of the 1995-2000 period rates from the University of the Philippines Population Institute medium II and low II series, respectively (Boulier, 1977). In the medium series, the rate for the year 2000 was based on a graphical extrapolation of the average 1995-2000 period rates from the high and low series. Total fertility rates for the intermediate years were obtained by graphical interpolation between the 1975 and 2000 levels.

FIGURE B-7.
Total Fertility Rates for the Philippines: Estimated 1960-70 and Projected 1970-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 55.2 years to 66.0 years for males and from 60.9 years to 72.8 years for females between 1970 and 2000. The life expectancies at birth for the year 2000 were estimated by extrapolating the 1970 level for both sexes according to the University of the Philippines Population Institute assumption of an average annual increase of approximately 0.4 years (Boulier, 1977). The resulting life expectancy at birth for both sexes in 2000 was split by the 1970 ratio of male and female life expectancies to the 1970 life expectancy for both sexes.

Migration. Estimated net international migration for the 1970-75 period was based primarily on data on immigrants to the United States and Canada (U.S. Immigration and Naturalization Service, 1971 and 1972, table 9; and Canada, Manpower and Immigration, 1970, table 9). It was assumed that the small amount of immigration to the Philippines, as exhibited by lifetime migration between 1965 and 1970 (National Census and Statistical Office, 1974b, table IV-11), was offset by Philippine emigration to other countries.

No international migration was assumed to have occurred during the 1976-2000 projection period.

Major Sources

Boulier, Bryan L. (Princeton University). 1977. Personal communication.

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Canada, Manpower and Immigration. 1970. **1970 Immigration Statistics.** Ottawa.

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Engracia, Luisa T. 1974. **Estimates of the Life Table Functions of the Philippines: 1970.** UNFPA-NCSO Population Research Project. Monograph No. 1. Manila.

Flieger, Wilhelm. (University of San Carlos, Philippines). 1977. Personal communication.

National Census and Statistics Office. 1974a. **Age and Sex Population Projections for the Philippines by Province: 1970-2000.** UNFPA-NCSO Population Research Project. Monograph No. 2. Manila.

__________. 1974b. **Philippines 1970 Census of Population and Housing.** National Summary, Vol. 2. Manila.

U.S. Immigration and Naturalization Service. 1971. **1970 Annual Report.** Washington, D.C.

__________. 1972. **1971 Annual Report.** Washington, D.C.

THAILAND

Base Data

Base date: July 1, 1970

Population. The base population data were derived from the April 1, 1970 census adjusted for 6.6 percent net underenumeration as estimated by a cohort analysis of the 1960 and 1970 censuses and accepting intercensal trends in fertility and mortality.

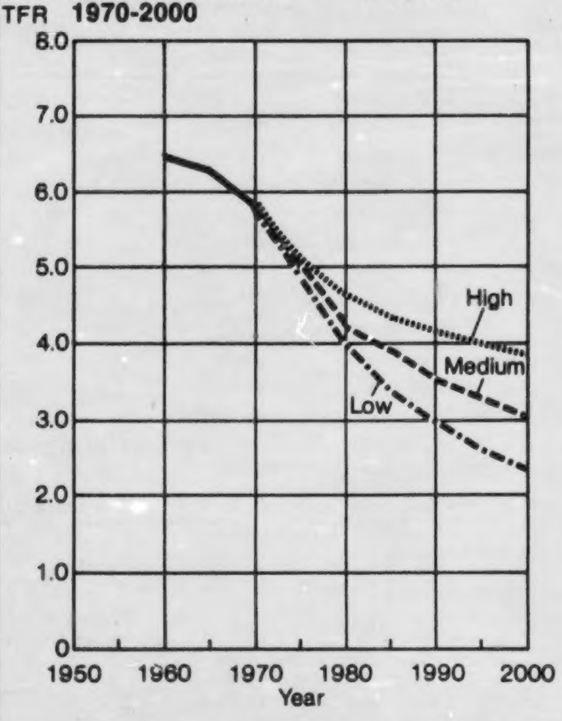
Fertility level. Age-specific fertility rates for 1970 were derived from an average of the 1968-69 and 1971-72 period age-specific marital fertility rates, by urban and rural areas reported in the Thai Longitudinal Study (Knodel and Pitaktepsombati, 1975, table 10), and were weighted to a national level by the proportion of females in each age group who were married and living in urban and rural areas according to the 1970 census (National Statistical Office, 1973, table 5). The resulting pattern of fertility for 1970 was adjusted slightly for irregularities.

Mortality level. Life tables were constructed for 1970 based on levels of life expectancy at birth by sex and were estimated by a graphic stable population technique and age-sex patterns of mortality based on observed changes in mortality patterns between 1964-65 and 1974-75 as shown in life tables from the Survey of Population Change (National Statistical Office, no date, table 7, and 1976b, table 6), adjusted by the logit technique (Brass and Coale, 1968, pp. 127-135).

Projections Assumptions

Fertility. The total fertility rate of 5.9 in 1970 was assumed to have declined by the year 1976 to 5.1 in the high series, 4.9 in the medium series, and 4.7 in the low series. In the high series, the 1976 rate was based on the assumption that the rate of decline between 1975 and 1976 would be 75 percent of the average annual rate of decline exhibited by the 1970 estimated rate and the 1974-75 rate reported in the Survey of Population Change (National Statistical Office, 1976b, table 4). In the low series, the rate for 1976 was derived by taking into consideration the average of the 1970-75 and 1975-80 period total fertility rates (derived from reported general fertility rates) from the National Statistical Office (1976a, table 1), and results from the Survey of Fertility in Thailand (Institute of Population Studies, Chulalongkorn University, and National Statistical Office, 1977, table 22). In the medium series, the rate for 1976 assumed an acceleration of the decline in the rates between 1964-65 (National Statistical Office, no date, table H) and 1970, taking into consideration the average of the high and low series for 1975.

FIGURE B-8.
Total Fertility Rates for Thailand: Estimated 1960-70 and Projected 1970-2000



The rates for 1976 were assumed to have declined further by the year 2000 to 3.9 in the high series, 3.1 in the medium series, and 2.4 in the low series. In the high series, the rate for the year 2000 was based on the assumption that the 1974-75 rate reported in the Survey of Population Change (National Statistical Office, 1976b, table 4) would decline by 25 percent. The rate for the year 2000 in the medium series was based on an average of the 1995-2000 and 2000-05 period total fertility rates (derived from reported general fertility rates) from the National Statistical Office (1976a, table 1) medium- and low-projection series. The rate for the year 2000 in the low series was based on the average of the 1995-2000 and 2000-05 period rates (derived from reported general fertility rates) from the National Statistical Office (1976a, table 1) low projection series.

Mortality. In all series, life expectancy at birth was assumed to increase from 56.5 years to 57.3 years for males and from 59.5 years to 60.7 years for females between 1970 and 1976 based on estimated trends between the 1970 and 1974-75 life expectancies at birth, by sex. In all series, life expectancy at birth was assumed to increase from the 1976 levels to 65.2 years for males and to 69.0 years for females by 2000. The life expectancies at birth for the year 2000 were estimated by extrapolating the 1975 estimated level for both sexes by the National Statistical Office (1976a, p. 2) assuming an average annual increase of 0.33 years. The resulting levels were then estimated by sex based on the 1974-75 life expectancies by sex.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Brass, William, and Ansley J. Coale. 1968. Chapter III in William Brass, et al., **The Demography of Tropical Africa.** Princeton.

Institute of Population Studies, Chulalongkorn University, and National Statistical Office. 1977. **The Survey of Fertility in Thailand: Country Report.** Vol. I. Bangkok.

Knodel, John, and Pichit Pitaktepsombati. 1975. "Fertility and Family Planning in Thailand: Results from Two Rounds of a National Study." **Studies in Family Planning.** Vol. 6. No. 11.

National Statistical Office. No date. **Report of the Survey of Population Change, 1964-65.** Bangkok.

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SOUTH KOREA

Base Data

Base date: July 1, 1970

Population. The base population data were from the October 1, 1970 census adjusted for 5.1 percent net underenumeration, and estimated at the midyear. The census was adjusted based on the results of the 1970 Post-Enumeration Survey, estimated sex ratios, and estimated births from 1960 to 1970.

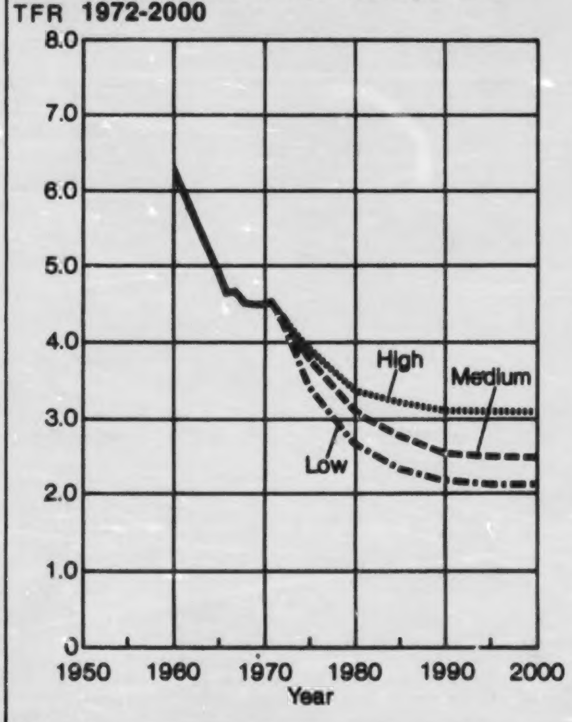
Fertility level. Age-specific fertility rates for 1970 were based on the results of the 1971 Fertility-Abortion Survey (Korean Institute for Family Planning, 1976, Appendix A).

Mortality level. Life tables were constructed for 1970 based on estimates of expectation of life at birth and the mortality pattern in the 1966 life tables. These 1966 life tables were derived from data from the 1966 Special Demographic Survey (Republic of Korea Economic Planning Board, 1970). The estimates of life expectancy for 1970 were derived by graphic extrapolation of life expectancies from the adjusted 1966 life tables, taking into account estimates of life expectancy for both sexes for 1970.

Projection Assumptions

Fertility. The total fertility rate of 4.5 in 1970 declined to 4.4 in 1972, and was assumed to have declined by 1976 to 3.8 in the high series, 3.6 in the medium series, and 3.2 in

FIGURE B-9.
Total Fertility Rates for South Korea: Estimated 1960-72 and Projected 1972-2000



the low series. In the medium series the fertility rate for 1976 was based on the assumption that the average annual decline in fertility between 1972 and 1976 was the same as the decline observed between 1960 and 1966 (Korean Institute for Family Planning, 1976, Appendix A), a time of rapidly declining fertility. The change during the 1960-66 period was chosen because there was some indication that fertility began to decline rather rapidly after 1972. The 1976 rate for the high series was assumed to be 5 percent higher than the rate for the medium series and the rate for the low series was assumed to be 10 percent lower than the rate for the medium series.

It was assumed that the 1976 rates would decline by the year 2000 to 3.1 in the high series, 2.5 in the medium series, and 2.1 in the low series. The high and medium levels were chosen after considering past trends in fertility, and assumptions made by the East-West Population Institute (1977) and the United Nations (1975) for their population projections. The fertility rate for the low series was based on the assumption that a net reproduction rate of 1.00 would be reached in the year 2000.

Mortality. In all series, life expectancy at birth was assumed to increase from 62 years to 70 years for males and from 68 years to 74 years for females between 1970 and 2000. The life expectancies at birth for the year 2000 were estimated considering past trends in mortality, and projections made by the United Nations (1975) and by the East-West Population Institute (1977).

Migration. Estimated net international migration for the 1970-75 period was based primarily on data on immigrants to the United States and Canada from the Republic of Korea between 1970 and 1975 (U.S. Immigration and Naturalization Service, various years, and Canada, Manpower and Immigration, various years).

No internation migration was assumed to have occurred during the projection period.

Major Sources

Canada, Manpower and Immigration. Various years. **Immigration Statistics.** Ottawa.

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Korean Institute for Family Planning. 1976. **The Increasing Utilization of Induced Abortion in Korea,** by Sung-Bong Hong and Walter B. Watson. Seoul.

Republic of Korea Economic Planning Board. 1970. **A Comprehensive Study on 1966 Population Census.** Seoul.

United Nations. 1975. **Selected World Demographic Indicators by Countries, 1950-2000.** ESA/P/WP.55. New York.

U.S. Immigration and Naturalization Service. Various years. **Annual Report.** Washington, D.C.

EGYPT

Base Data

Base Date: July 1, 1975

Population. The base population data were derived from the preliminary count of the November 1976 census, and were estimated for July 1, 1975, based on registered births and deaths, adjusted for underregistration (see below). Since only a preliminary 1976 census total was available, no attempt was made to adjust for coverage error. Because no age distribution from the 1976 census was available, the age distribution for 1975 from the United Nations medium variant projections was accepted (United Nations, 1976) as the base-year age distribution.

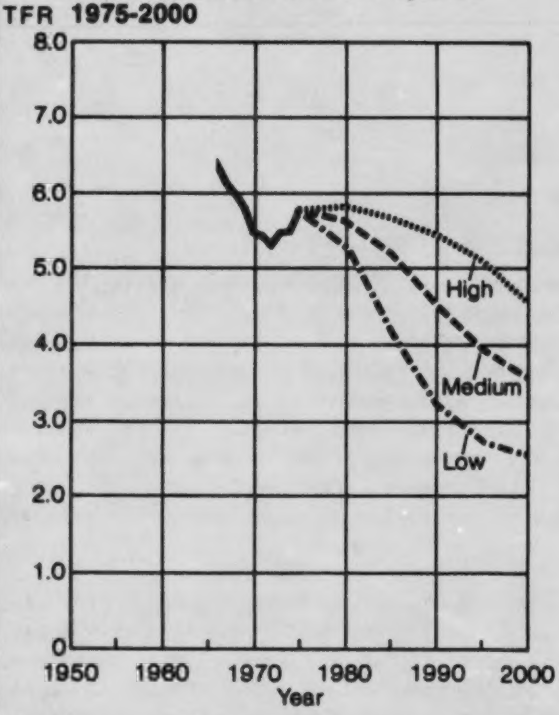
Fertility level. Age-specific fertility rates for 1975 were based on the registered number of births for 1975, adjusted for a 2-percent underregistration, and an estimate of the female population by age. Underregistration of births was estimated considering the level of underregistration during the period 1956-60 as estimated by Valaoras (1972, p. 22) and the trend of improvement in registration as estimated by Acsadi and Issa (1975, p. 23). The age pattern of fertility was assumed to be that of 1973, the last year for which data on births by age of mother are available.

Mortality level. A life table was constructed for 1975 based on preliminary data on registered deaths for that year, adjusted for 4-percent underregistration. Underregistration of deaths was estimated considering the levels and trends of registration completeness as estimated by Valaoras (1972, p. 22) and by Acsadi and Issa (1975, p. 23). The Coale-Demeny north region model life table (Coale and Demeny, 1966) was found which, when applied to the 1975 estimated age distribution, gave the correct number of deaths for ages 1 and over. An infant mortality rate was calculated from an estimate of the number of infant deaths and adjusted registered births.

Projection Assumptions

Fertility. The total fertility rate of 5.8 in 1975 was assumed to have declined by the year 2000 to 4.6 in the high series, 3.6 in the medium series, and 2.6 in the low series. In the medium series, the rate for the year 2000 was based on the ideal family size in Alexandria in the mid-1960's and in Cairo in 1970 (Toppozada, 1973, p. 316, and Khalifa, 1973, p. 431) adjusted downward 10 percent to allow for infertility and for an expected decline in the desired family size as the actual level of fertility declines. The 3.6 figure is also the same as that for 1995-2000 in the United Nations medium-variant projections (United Nations, 1975). The rate for the year 2000 in the high and low series was assumed to be ± one child from that for the medium series. A large range between the high and low series was chosen because of the great uncertainty in future fertility trends in Egypt. The large fertility decline that had been taking place in Egypt since the mid-1960's ended abruptly in 1972, and since then fertility has been rising sharply. Although all three series assume this fertility rise will abate, they differ by how rapidly it is assumed fertility will return to the 1972 levels.

FIGURE B-10.
Total Fertility Rates for Egypt: Estimated 1966-75 and Projected 1975-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 53.6 years to 62.5 years for males and from 54.9 years to 65.0 years for females between 1975 and 2000. The life expectancies at birth for the year 2000 were estimated considering past trends in mortality, mortality trends in other countries of the region, United Nations projections, and expected improvements in the social, economic, and health sectors of the country.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Acsadi, G. and M.S. Issa. 1975. **Considerations on Arabic Model Life Tables and Egyptian Mortality.** Cairo Demographic Centre Seminar on Mortality Trends and Differentials in Some Arab and African Countries. Cairo.

Coale, Ansley J. and Paul Demeny. 1966. **Regional Model Life Tables and Stable Populations.** Princeton University Press, Princeton.

Khalifa, Atef M. 1973. "A Proposed Explanation of the Fertility Gap Differentials by Socio-Economic Status and Modernity: The Case of Egypt." **Population Studies.** Vol. 27, No. 3. London.

Toppozada, H.K. 1973. "Research in Family Planning in Alexandria." In **Egypt: Population Problems and Prospects,** edited by Abdel R. Omran. Carolina Population Center, University of North Carolina at Chapel Hill.

United Nations. 1975. **Selected World Demographic Indicators by Countries, 1950-2000.** ESA/P/WP.55. New York.

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Valaoras, V.G. 1972. **Population Analysis of Egypt (1935-70).** Occasional Paper No. 1. Cairo Demographic Centre. Cairo.

NIGERIA

Base Data

Base date: July 1, 1975

Population. The base population data are from the United Nations medium-variant projections of the population by age and sex for 1975 (United Nations, 1976b). The United Nations states that the total population estimate for 1975 is "based on results of the census of 5-8 November, 1973, including adjustment for estimated overenumeration" (United Nations, 1976a, table 3, note 31). The implied net overenumeration can be calculated as approximately 19 percent.

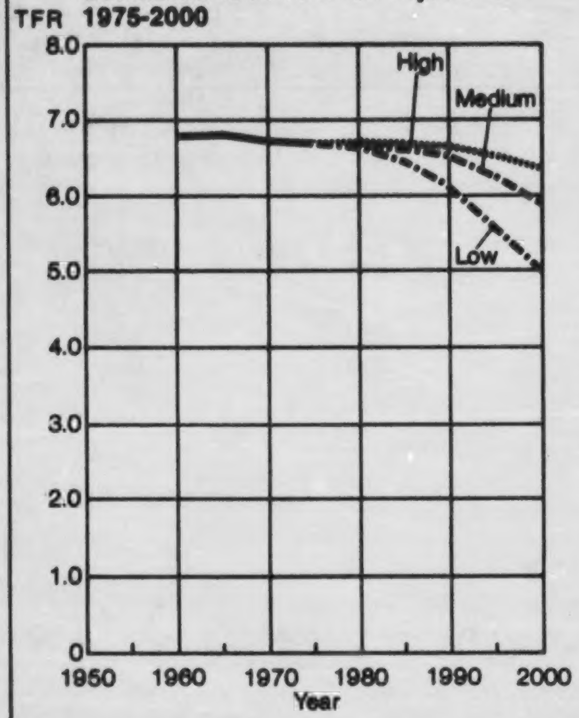
Fertility level. The total fertility rate for 1975 is an average of the 1970-75 and 1975-80 period rates from the United Nations medium-variant projections (United Nations, 1975, p. 55). The age pattern of fertility for 1975 was taken from the United Nations model age pattern of fertility for the African region at an equivalent fertility level (United Nations, 1977b, pp. 7-11 and United Nations, 1976).

Mortality level. The life expectancy by sex in 1975 is an average of the 1970-75 and 1975-80 United Nations medium-projection series (United Nations, 1975). Coale-Demeny south region model life tables (Coale and Demeny, 1966) at an equivalent level of life expectancy, by sex, were used to obtain the pattern of mortality.

Projection Assumptions

Fertility. The total fertility rate of 6.7 in 1975 was assumed to decline by the year 2000 to 6.4 in the high series, 5.9 in the medium series, and 5.0 in the low series. The trends in the fertility rates between 1975 and 2000 are approximately those implied by trends in the total fertility rate between the 1970-75 and 1995-2000 periods in the United Nations high, medium, and low projections series, respectively (United Nations, 1975).

FIGURE B-11.
Total Fertility Rates for Nigeria: Estimated 1960-75 and Projected 1975-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 41 years to 53 years for males and from 44 years to 57 years for females between 1975 and 2000. The life expectancies in all series are those assumed by the United Nations in the medium-variant projection (United Nations, 1975).

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Coale, Ansley J. and Paul Demeny. 1966. **Regional Model Life Tables and Stable Populations.** Princeton University Press, Princeton.

United Nations. 1975. **Selected World Demographic Indicators by Countries, 1950-2000.** ESA/P/WP.55. New York.

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________. United Nations. 1976a. **Demographic Yearbook 1975.** New York.

________. 1976b. **Population by Sex and Age for Regions and Countries, 1950-2000, as Assessed in 1973: Medium Variant.** ESA/P/WP.60. New York.

________. 1977a. **United Nations Projections as Assessed in 1973. Selected Indicators.** (Revised) Computer printout, unpublished.

________. 1977b. **World Population as Assessed in 1973.** Population Studies, No. 60. New York.

BRAZIL

Base Data

Base date: July 1, 1970

Population. The July 1, 1970 population is derived from the September 1, 1970 census population (Brazil Departmento de Censos, 1973, table 1). The 1970 census population was adjusted by a cohort analysis of the 1950, 1960, and 1970 censuses, by age and sex, and by assuming certain trends of the sex ratios in each age cohort during the intercensal periods. The 1970 adjusted census population was estimated for July 1, 1970 using an estimated growth rate for 1970, based on preliminary estimates of crude birth and death rates and assuming no net migration.

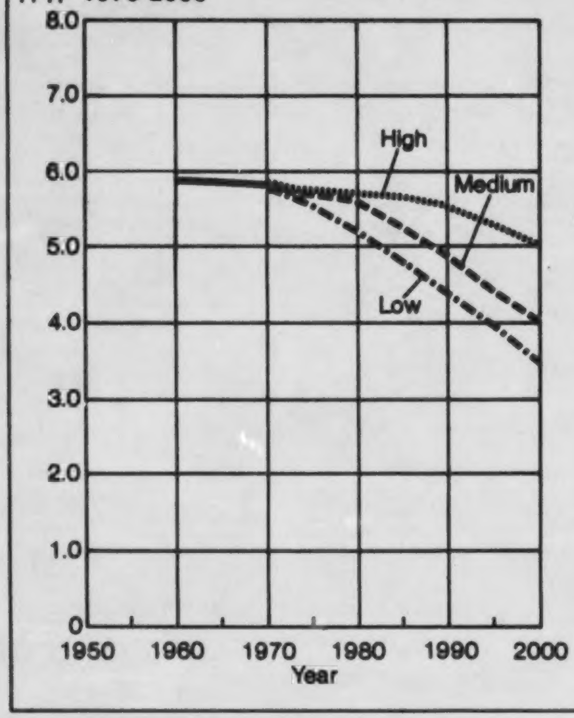
Fertility level. Age-specific fertility rates for 1970 were derived by applying Arriaga and Anderson's fertility estimation method (Arriaga and Anderson, 1976) to children ever born data from the 1940, 1950, and 1960 censuses adjusted by Carmen Arretx (1975, table 5), and children ever born data from the final results of the 1970 census (Brazil Departamento de Censos, 1973, tables 28 and 31).

Mortality level. Life expectancies at birth for 1970 were estimated to be 59.2 years for males and 62.8 years for females using Irwin and Madeira's intercensal life tables for the 1960 to 1970 period (1972, p. 709) and past trends in life expectancies at birth (Arriaga, 1968, p. 42). The 1970 age patterns of mortality were constructed assuming that the pattern of change in the age-specific mortality probabilities between the Irwin and Madeira 1960 to 1970 intercensal life tables and the 1970 estimated life expectancies were the same as those implied by the Coale-Demeny south region model life tables (Coale and Demeny, 1966) at similar levels of mortality.

Projection Assumptions

Fertility. The total fertility rate of 5.8 in 1970 was assumed to have declined by the year 2000 to 5.0 in the high series, 4.0 in the medium series, and 3.5 in the low series. The rates in 2000 for the high, medium, and low series were estimated after considering official population projections (Brazil IBGE, 1974, p. 125). The population policy in Brazil has been essentially pronatalist. There has been, however, some acknowledgment of the "... responsibility to provide information and means of family planning to all Brazilians who voluntarily choose to plan their families" (UNFPA, 1975, p. 55). Therefore, it has been assumed that fertility in Brazil will not decline as rapidly as in those Latin American countries where family planning receives active support.

FIGURE B-12.
Total Fertility Rates for Brazil: Estimated 1960-70 and Projected 1970-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 59.2 years to 68.2 years for males and from 62.8 years to 71.8 years for females between 1970 and 2000. The life expectancies at birth for the year 2000 were graphically extrapolated based on past trends in mortality as evaluated by Arriaga for 1950 and 1960 (1968, p. 42), and Irwin and Madeira for the 1960 to 1970 period (1972, p. 709).

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Arretx, Carmen. 1975. **Fertility Estimates Derived from Information on Children Ever Born Using Data from Successive Censuses.** University of North Carolina. Chapel Hill.

Arriaga, Eduardo E. 1968. **New Life Tables for Latin American Populations in the Nineteenth and Twentieth Centuries.** Population Monograph Series, No. 3. University of California.

Arriaga, Eduardo E. and Patricia Anderson. 1976. "An Approach for Estimating Fertility from Census and/or Survey Information on Children Ever Born by Age of Mother." Paper presented at the annual meeting of the Population Association of America, Montreal. Unpublished.

Brazil Departmento de Censos. 1973. **Censo Demográfico Brasil. VIII Recenseamento General—1970. Série Nacional. Vol. 1. Rio de Janeiro.**

Brazil IBGE. 1974.

Brazil IBGE. 1974. **Encontro Brasileiro de Estudos Populacionais Resumas de Communicacoes.** Guanabara.

Coale, Ansley J., and Paul Demeny. 1966. **Regional Model Life Tables and Stable Populations.** Princeton University. Princeton.

Irwin, Richard and Joao L. Madeira. 1972. "Deducão de Uma Tábua de Vida atraves de Análise Demográfica Brasil, 1960/70." **Revista Brasileira de Estatística.** Ano XXXIII, No. 132. Rio de Janeiro.

United Nations Fund for Population Activities (UNFPA). 1975. **Inventory of Population Projects in Developing Countries Around the World: 1973/74.** New York.

MEXICO

Base Data

Base date: July 1, 1970

Population. The July 1, 1970 population is based on the January 28, 1970 census population (Mexico Dirección General de Estadística, 1972, table 5), and was adjusted by a cohort analysis of the 1950, 1960, and 1970 censuses, by age and sex, using registered births and deaths adjusted for underregistration (U.S. Bureau of the Census, 1978, tables 1, 2, and 3). The 1970 adjusted census population was advanced to July 1, 1970 using registered births and deaths for 1970 and adjusted for underregistration and estimated net emigration, based primarily on the reported number of immigrants from Mexico into the United States and Canada during 1970 (U.S. Immigration and Naturalization Service, 1971, table 9 and Canada Department of Manpower and Immigration, 1971, table 9).

Fertility level. Age-specific fertility rates were calculated from births registered in 1970 and adjusted for a 3-percent underregistration and from the 1970 census female population adjusted for underenumeration (U.S. Bureau of the Census, 1979, table 2).

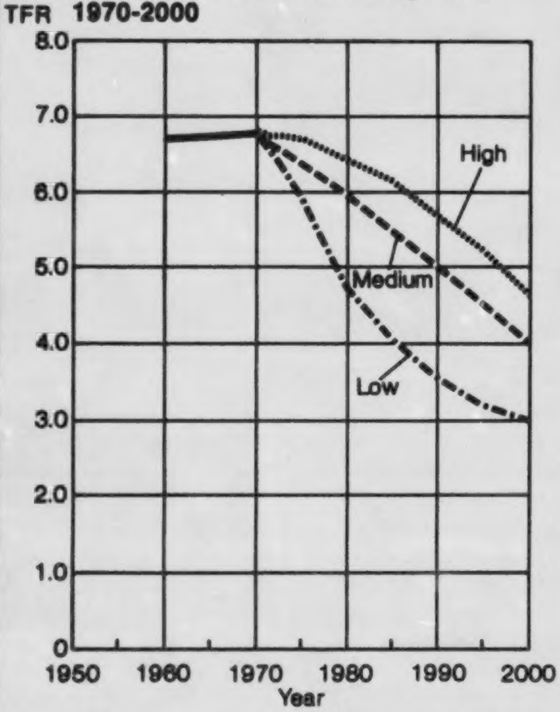
Mortality level. A life table was constructed for the 1969-71 period using age-sex specific death rates derived from weighted averages of registered deaths for 1969, 1970, and 1971 (adjusted for underregistration) and the adjusted census population (U.S. Bureau of the Census, 1979, table 2).

Projection Assumptions

Fertility. The total fertility rate of 6.7 in 1970 was assumed to have declined by the year 2000 to 4.7 in the high series, 4.0 in the medium series, and 3.0 in the low series. The high and medium series for 2000 were derived by considering the United Nations medium- and low-variant projections, respectively (United Nations, 1975, p. 78). The rate in 2000 for the low series was assumed to be one child smaller than the rate for the medium series. The rates for the intermediate years were obtained by graphic interpolation.

Although data for registered births are available through 1976, the quality of the registration system in recent years is suspect. However, registered data through 1976, adjusted for underregistration, were considered in making the projections.

FIGURE B-13.
Total Fertility Rates for Mexico: Estimated 1960-70 and Projected 1970-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 58.8 years to 69.0 years for males and from 62.8 years to 72.7 years for females between 1969-71 and 2000. The life expectancies at birth for the years 2000 were estimated considering past trends in mortality and United Nations mortality projections (United Nations, 1975, p. 78). Life expectancies at birth for 1971 through 1976 were projected considering registered deaths adjusted for 3 percent underregistration.

Migration. Annual estimates of net migration from 1970 to 1975 were based primarily on the reported number of immigrants into the United States and Canada by age and sex (U.S. Immigration and Naturalization Service, various years, and Canada Department of Manpower and Immigration, various years).

No international migration was assumed to have occurred during the period from 1975 to 2000.

Major Sources

Canada Department of Manpower and Immigration. Various years. **Immigration Statistics.** Ottawa.

Mexico Dirección General de Estadística. 1972. **IX Censo General de Pobalción, 28 de Enero de 1970: Resumen General.** Mexico City.

United Nations. 1975. **Selected World Demographic Indicators by Countries, 1950-2000.** ESA/P/WP.55. New York.

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U.S. Immigration and Naturalization Service. Various years. **Annual Report of the Immigration and Naturalization Service.** U.S. Government Printing Office. Washington, D.C.

TEMPERATE SOUTH AMERICA

Component projections were prepared for the United Nations subregion of Temperate South America.[2] Unlike the rest of Latin America which was considered less developed by the United Nations, Temperate South America was classified as a more developed region at the time this report was prepared (United Nations, 1977, p. 2) and the projection assumptions correspondingly reflected its "more developed status."

Base Data

Base date: July 1, 1975

Population. The base population data were from the United Nations medium-variant projections for 1975 (United Nations, 1976b).

Fertility level. Total fertility rates of 3.2 for the high series, and 3.1 for the medium and low series in 1975 were suggested by the United Nations high, medium, and low projections for the region (United Nations, 1975) and recent fertility data for the countries of the region.

The age patterns of fertility for 1975 are from the United Nations model age patterns of fertility for the Latin America region (United Nations, 1977, pp. 7-11 and United Nations 1976a).

Mortality level. The United Nations estimates from the medium variant for life expectancies, by sex, for the 1970-75 and 1975-80 periods were averaged and the averages were used as the life expectancies, by sex, for 1975 (United Nations, 1975). Coale-Demeny west region model life tables (Coale and Demeny, 1966) at an equivalent level of life expectancy were assumed to adequately represent the pattern of mortality.

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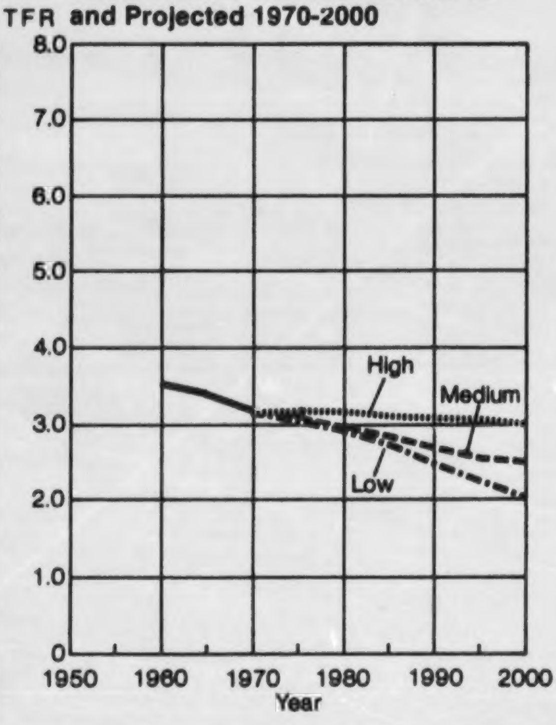
[2] Temperate South America consists of the countries of Argentina, Chile, Uruguay, and the Falkland Islands (United Nations, 1977, p. 2).

Projection Assumptions

Fertility. The total fertility rate of 3.2 in 1975 was assumed to have declined by the year 2000 to 3.0 in the high series, from 3.1 in 1975 to 2.5 by the year 2000 in the medium series, and from 3.1 in 1975 to 2.0 by the year 2000 in the low series. The rates in the medium and low series by the year 2000 are approximately those implied by the trend between 1970-75 and 1995-2000 in the United Nations medium and low variants (United Nations, 1975). The estimated total fertility rate of 3.0 in the high series by the year 2000 in this report is slightly higher than the United Nations high variant total fertility rate of 2.8 by 2000 (United Nations, 1975).

FIGURE B-14.
Total Fertility Rates for Temperate South America: Estimated 1960-70 and Projected 1970-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 64 years to 68 years for males and from 70 years to 74 years for females between 1975 and 2000. The life expectancies in all series are those assumed by the United Nations in the medium-variant projections (United Nations, 1975). The period values in the United Nations series for the life expectancies, by sex, for the 1970-75 and 1975-80 periods were averaged and the resulting values assumed to apply to 1975 and so on to the 1995-2000 period which was extrapolated to estimate values for the year 2000.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Coale, Ansley J. and Paul Demeny. 1966. **Regional Model Life Tables and Stable Populations.** Princeton University Press, Princeton.

United Nations. [1976a]. Paper containing model age patterns of fertility (age-specific fertility rates) for given levels of gross reproduction rates by regions of the world. Computer printout, unpublished.

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__________. 1977. **World Population as Assessed in 1973.** Population Studies, No. 60. New York.

NORTHERN AMERICA

Canada, Bermuda, Greenland, St. Pierre and Miquelon, and the United States comprise the United Nations region "Northern America" (United Nations, 1977b, table 28). Component population projection series were prepared for both Canada, including the population of Bermuda, Greenland, and St. Pierre and Miquelon, and the United States.

Fertility and mortality base data for Canada including Bermuda, Greenland, and St. Pierre and Miquelon were estimated on the basis of official Canadian data. Since Canada's population is over 99 percent of the combined population of these areas, separate assumptions for the three smaller areas would not significantly affect the assumption that the combined population could be projected using Canadian fertility and mortality data.

CANADA

(including Bermuda, Greenland, and St. Pierre and Miquelon)

Base Data

Base date: July 1, 1975

Population. The base population data were from the official 1975 midyear population estimate of Canada (United Nations Statistical Office, 1977). Total population estimates for Bermuda, Greenland, and St. Pierre and Miquelon for midyear 1975 (U.S. Bureau of the Census current estimates) were added to the 1975 total for Canada.[3] The total populations

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[3] Total population estimates, midyear 1975, are as follows:

Country or area	Population
Canada	22,799,800
Bermuda	59,719
Greenland	50,047
St. Pierre and Miquelon	5,983

of these three areas were distributed by age and sex in the same proportions as the age-sex distribution of Canada.

Fertility level. The total fertility rate for 1975 was estimated by considering the provisional 1975 official Canadian estimate of total births (United Nations, 1977a) and the latest available official fertility rates for Canada for 1972 through 1974 (1972 and 1973 data from United Nations, 1976, table 24; 1974 data from United Nations Statistical Office, 1977).

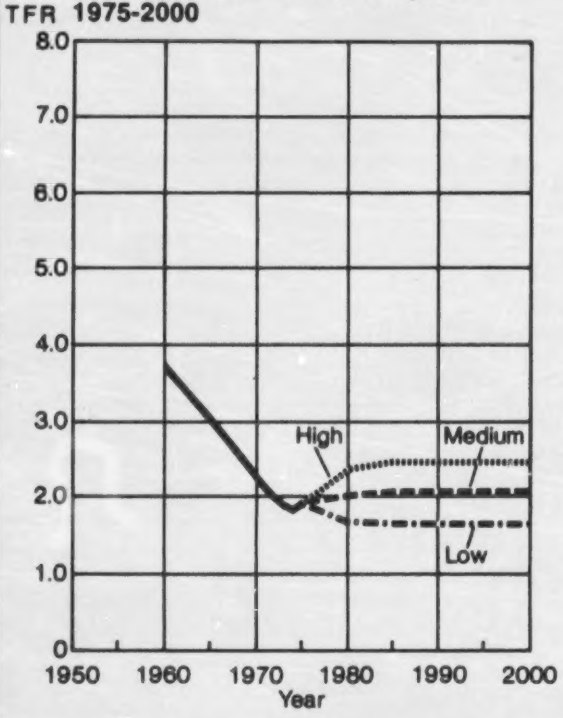
The age pattern of fertility for 1975 was the average pattern of the 1972 through 1974 reported age-specific fertility rates.

Mortality level. Life tables for 1975 were estimated based on life expectancies at birth and age-sex patterns of mortality for 1975 as shown in official Canadian population projections (Statistics Canada, 1974, tables 3.2 and 3.3).

Projection Assumptions[4]

Fertility. The total fertility rate in 1975 was assumed to have increased to 2.5 by the year 1985 and remained constant at the 2.5 level to the year 2000 in the high series. In the medium series, the 1975 TFR was assumed to have increased to 2.1 by 1984 and remained constant at that level to the year 2000. In the low series, the 1975 TFR was assumed to have declined to 1.7 in 1981 and remained constant to 2000. These fertility rates in the year 2000 are approximately consistent with the high, medium, and low fertility projections of the official Canadian projections (Statistics Canada, 1974, table 6.1).

FIGURE B-15.
Total Fertility Rates for Canada: Estimated 1960-75 and Projected 1975-2000



Mortality. In all series, life expectancy at birth was assumed to increase from 69.6 years to 70.2 years for males between 1975 and 1986 and then held constant at the 1986 level to the year 2000. In all series, life expectancy at birth was assumed to increase from 76.7 years to 78.4 years for females between 1975 and 1986 and then held constant at the 1986 level to the year 2000. The levels of life expectancies in the year 1986 and the patterns of change in these projections are the same as the levels and patterns in Canada's official projections (Statistics Canada, 1974, table 3.3).

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Statistics Canada. 1974. **Population Projections for Canada and the Provinces, 1972-2001.** Ottawa.

United Nations. 1976. **Demographic Yearbook 1975.** New York.

__________. 1977a. **Population and Vital Statistics Report.** Quarterly, April 1. New York.

__________. 1977b. **World Population Prospects as Assessed in 1973.** Population Studies, No. 60. New York.

United Nations Statistical Office. 1977. Personal communication.

UNITED STATES

Component population projections for the United States were prepared in the Population Division, U.S. Bureau of the Census. The projection series used in this report assume no net immigration between 1975 and 2000. The high and low series are from unpublished computer printouts prepared especially for this report. Population projections for the medium series (Series II-X) and a discussion of the methodology and assumptions used in preparing the projections are contained in:

U.S. Bureau of the Census, 1977, "Projections of the Population of the United States: 1977 to 2050," **Current Population Reports,** Series P-25, No. 704, Washington, D.C.

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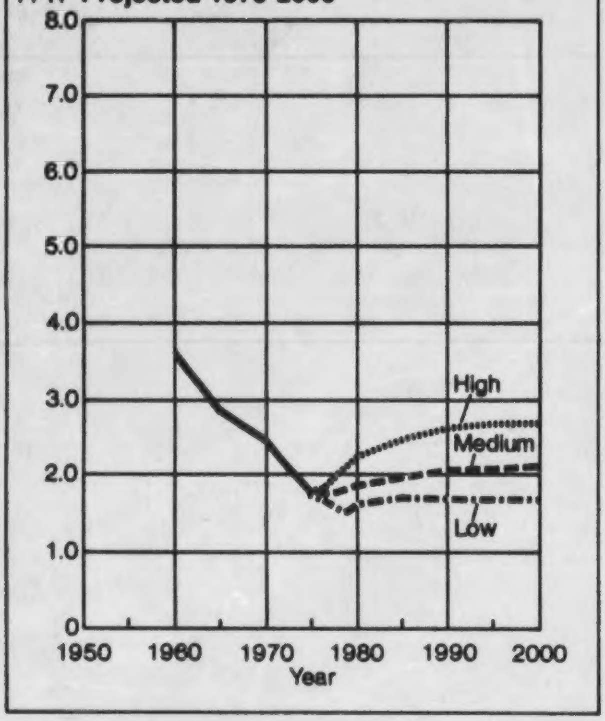
[4] Fertility and mortality assumptions were prepared for Canada, Bermuda, Greenland, and St. Pierre and Miquelon on the basis of projected trends shown in official Canadian projections assuming that these trends are generally applicable to all areas covered in this projection set.

FIGURE B-16.
Total Fertility Rates for the United States: Estimated 1960-75 and Projected 1975-2000



JAPAN

Base Data

Base date: July 1, 1975

Population. The base population data were derived from the official midyear total population estimate for 1975 (United Nations Statistical Office, 1977) which is based on the population census of October 1, 1975. The 1975 census age-sex distribution (Bureau of Statistics, 1976, table 1) was assumed to apply to the midyear total population estimate.

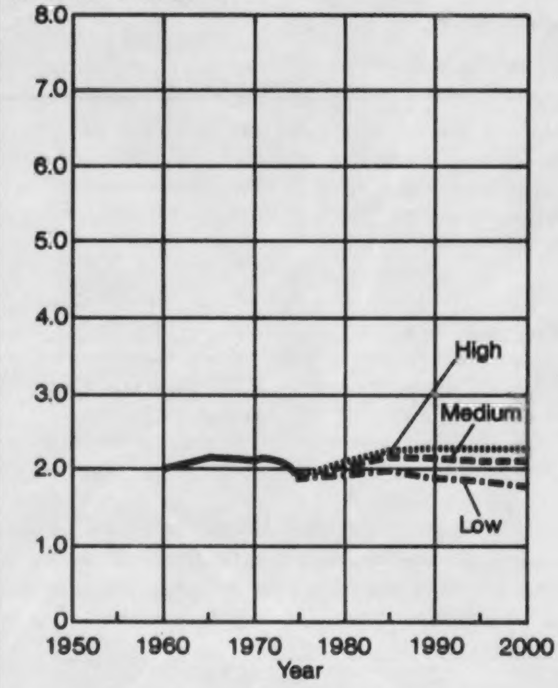
Fertility level. The 1975 total fertility rate and the corresponding age-specific fertility rates are the offical rates as reported to the United Nations Statistical Office (1977).

Mortality level. Offical life tables for the period April 1, 1974 to March 31, 1975 were used for 1975 (Institute of Population Problems, 1976, table 1).

Projection Assumptions

Fertility. The total fertility rate of 1.9 in 1975 was assumed to have increased to 2.3 by 1985 and to have remained at that level through the year 2000 in the high series. In the medium series, the total fertility rate of 1.9 in 1975 was assumed to have increased to 2.2 in 1985 and then to decrease from the 2.2 level to 2.1 in the year 2000. In the low series, the 1975 rate of 1.9 was assumed to have increased to 2.0 by 1985 and then to decrease to 1.8 by the year 2000. These fertility assumptions for the years 1985 and 2000 are the assumptions shown in the official population projections of Japan (Institute of Population Problems, 1975, table 5).

FIGURE B-17.
Total Fertility Rates for Japan: Estimated 1960-75 and Projected 1975-2000



Mortality. In all series, life expectancy at birth for males was assumed to increase from 71 years to 73 years between 1975 and 1985 and then hold constant at the 1985 level to the year 2000. In all series, life expectancy at birth for females was assumed to increase from 76 years to 78 years between 1975 and 1985 and was then held constant at the 1985 level to the year 2000. The levels of life expectancies in the year 1985 and the patterns of change in these projections are the same as the levels and patterns in Japan's official projections (Institute of Population Problems, 1975, pp. 40 and 48).

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Bureau of Statistics. 1976. **1975 Population Census of Japan: Prompt Report of the Basic Findings.** Tokyo.

Institute of Population Problems. 1975. "Population Projections for Japan, 1970-2050, Estimated in February

1975," by Tatsuya Itoh and Chizuko Yamamoto. **The Journal of Population Problems.** No. 135, pp. 39-48. Tokyo.

__________. 1976. **The 28th Abridged Life Tables (April 1, 1974 - March 31, 1975).** Research Series, No. 212. Tokyo.

United Nations Statistical Office. 1977. Personal communication.

AUSTRALIA

Base Data

Base date: July 1, 1975

Population. The base population data were derived from the 1975 total population estimate from official projections exclusive of net migration after June 30, 1970 (Australian Bureau of Statistics, 1973, p. 145). The base of the official projections was the 1966 census and preliminary results of the 1971 census.[5]

Fertility level. The 1970 total fertility rate of 2.85 used in the official Australian projections for the period 1972 through 2000 (medium projection) was used in this report as the rate for 1975 for the medium projection (Australian Bureau of Statistics, 1973, pp. 144 and 168).

The estimated rates for 1975 in the high and low series are 0.02 points higher and lower than the medium series 1975 rate.

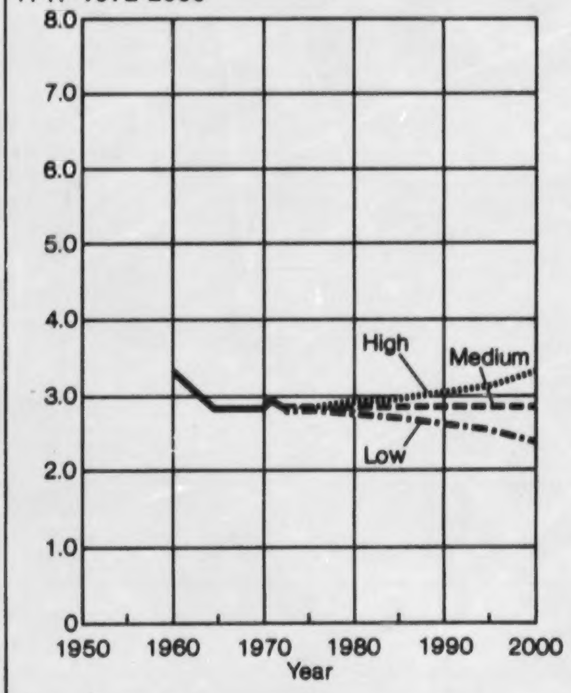
The age pattern of fertility for 1975 in all series is represented by the official age-specific fertility rates which correspond to the 1970 total fertility rate (Australian Bureau of Statistics, 1973, p. 168).

Mortality level. Official empirical life tables, based on the average age-specific mortality rates in the 3 years from 1965 through 1967, were assumed to apply to 1975 in the high, medium, and low projections in this report. (Australian Bureau of Statistics, 1973, pp. 144 and 181).

Projection Assumptions

Fertility. The total fertility rate of 2.87 in 1975 was assumed to have increased to 3.31 in the year 2000 in the high series. In the medium series, the 1975 rate of 2.85 was assumed to remain constant throughout the projection period 1975 through 2000 at the 1975 level, while in the low series, the 1975 rate of 2.83 was assumed to decline to 2.39 by the year 2000. The medium series constant fertility assumption is the projection of fertility shown in the Australian official projections for the period 1972-2000 (Australian Bureau of Statistics, 1973, p. 144). The low series follows the trend of fertility in the United Nations medium-projection series throughout the projection period, 1970-75 through 1995-2000 (United Nations, 1977). The high series shows a trend in the fertility rate which is the same distance above the constant fertility line as the distance which the low series fertility rates are below the constant fertility line.

FIGURE B-18.
Total Fertility Rates for Australia: Estimated 1960-72 and Projected 1972-2000



Mortality. In all series, life expectancy at birth was assumed to remain constant at the level assumed for 1975, 68 years for males and 74 years for females (Australian Bureau of Statistics, 1973, pp. 144 and 181). This is the same assumption made in the official projections.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Australian Bureau of Statistics. 1973. **Official Year Book of Australia.** No. 59. Canberra.

United Nations. 1975. **Selected World Demographic Indicators by Countries, 1950-2000.** ESA/P/WP.55. New York

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[5] Figures from official Australian population projections for the year 1975 including and excluding estimated net international migration are as follows:

Assumptions	1975 Population
Excluding estimates of net international migration	13,262,600
Including estimates of net international migration at 1966-70 levels	13,734,000

NEW ZEALAND

Base Data

Base date: July 1, 1975

Population. The base population data were derived from the March 31, 1975 total population estimate (Department of Statistics, 1977, p. 6). The age-sex distribution of the estimated March 23, 1976 population (Department of Statistics, 1977, p. 8) was assumed to apply to the 1975 total population estimate.

Fertility level. The 1975 total fertility rate is based on an extrapolation of the 1962 through 1974 trend of the officially estimated fertility. The age pattern of fertility for 1975 is represented by the official age-specific fertility rates which correspond to the reported 1974 rate (United Nations, 1976, table 24).

Mortality level. Empirical life tables were derived based on the average age-specific mortality rates in the years 1970-72 (United Nations, 1974, table 6 and 1975, table 25).

Projection Assumptions

Fertility. The assumptions for the low series followed generally the assumptions in the New Zealand official projections for 1975-2006 (Department of Statistics, 1977, p. 6). In the low series, the trend of rates for 1962 through 1974 was extended to 1980 with the 1975 rate of 2.5 declining to 2.0 by the year 2000. The medium and high series rates were then derived relative to the low projection using less extreme declines in the medium series and a slight increase in the high series. The rate in the medium series shows a decline from the 1975 level of 2.5 to 2.2 in the year 2000. The high series shows a slight increase in the 1975 level of 2.5 to a rate of 2.6 by the year 2000.

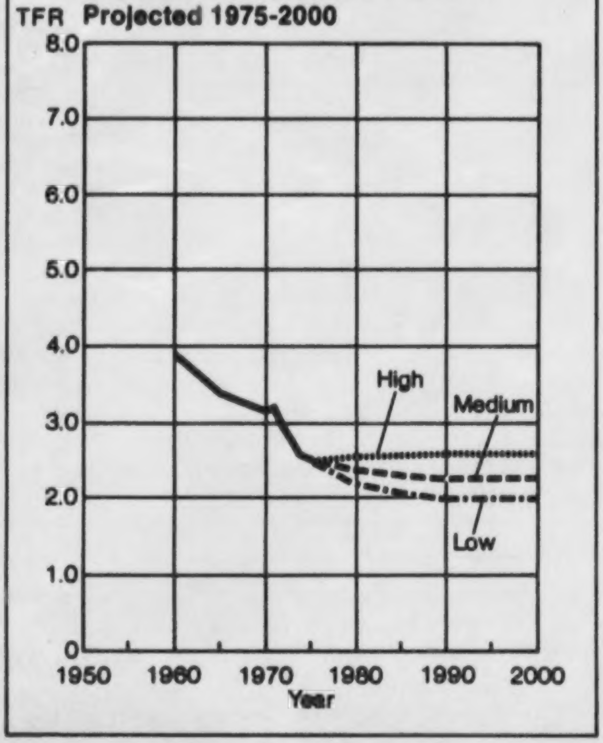

FIGURE B-19.
Total Fertility Rates for New Zealand: Estimated 1960-75 and Projected 1975-2000

Mortality. In all series, life expectancy at birth was assumed to remain constant at the level assumed for 1975, 68 years for males and 75 years for females (Department of Statistics, 1977, p. 6 and United Nations, 1974, table 6 and 1975, table 25). The same assumption of constant mortality at these levels was made in the official projections.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Department of Statistics. 1977. **Monthly Abstract of Statistics.** June. Wellington.

United Nations. 1974. **Demographic Yearbook 1973.** New York.

__________. 1975. **Demographic Yearbook 1974.** New York.

__________. 1976. **Demographic Yearbook 1975.** New York.

EASTERN AND WESTERN EUROPE

Base Data

Base date: July 1, 1975

Population. The regions of Eastern and Western Europe in this report comprise 8 countries and 27 countries, respectively. The 1975 base total population estimates for these projections were the 1975 official population estimates of the individual countries of Europe (United Nations, various dates) aggregated to totals for Eastern and Western Europe. The 1975 age-sex distributions from the United Nations medium-variant projections for European regions (United Nations, 1976b) were redefined to correspond to the regions Eastern and Western Europe as designated in these projections.[6] The resulting 1975 age-sex distributions were adjusted considering recent trends in vital statistics in these countries.

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[6] The United Nations allocated countries to regions on a geographical basis. The allocation in these projections of European countries to the regions of Eastern and Western Europe followed generally the United Nations pattern except as noted below:

1. Albania and Yugoslavia were added to the United Nations Eastern European region and designated "Eastern Europe" for these projections.
2. The following aggregation was designated "Western Europe" in these projections: (a) United Nations regions of Southern Europe excluding Albania and Yugoslavia and including Andorra, Gibraltar, and San Marino; (b) United Nations region Northern Europe including the Channel and Faeroe Islands and the Isle of Man; and (c) the United Nations region Western Europe including Liechtenstein and Monaco.

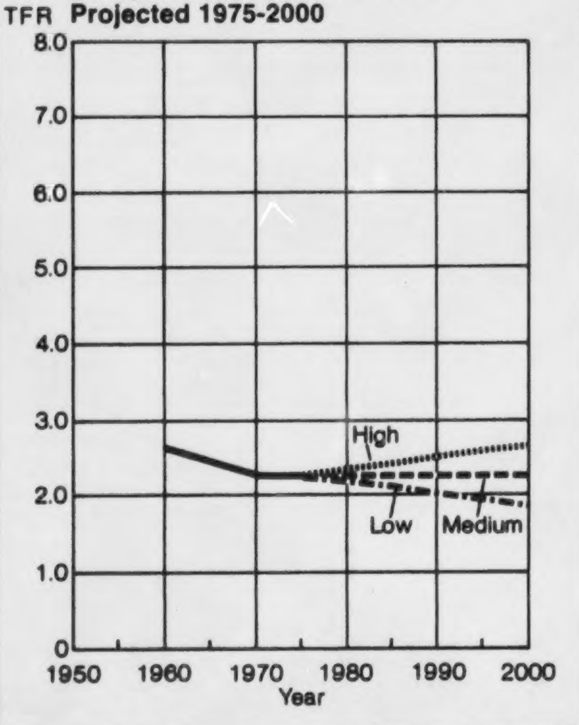
Fertility. The 1975 total fertility rates for Eastern and Western Europe were weighted averages of the most recent officially reported fertility rates (Princeton University, 1977). The age patterns of fertility for 1975 are from the United Nations model age patterns of fertility for appropriate regions at equivalent levels of fertility (United Nations, 1977, pp. 7-11 and United Nations, 1976a).

Mortality levels. The United Nations life expectancies for the 1970-75 and 1975-80 periods for the countries of Europe from the medium variant were averaged and the averages, weighted by the populations of the appropriate countries of Eastern and Western Europe, were used as the life expectancies for 1975 (United Nations, 1975). Coale-Demeny west region model life tables (Coale and Demeny, 1966) at an equivalent level of life expectancy, by sex, were used to represent the pattern of mortality.

Projection Assumptions

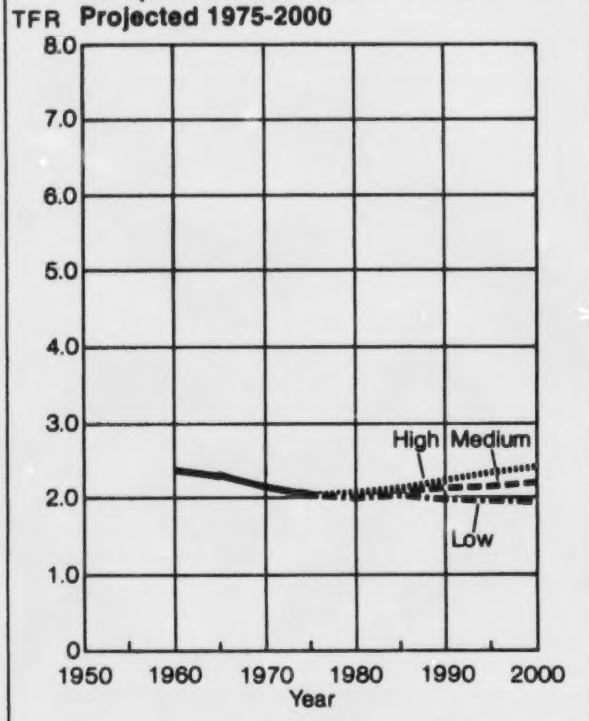
Fertility. The total fertility rate in Eastern Europe of 2.3 in 1975 was assumed to have increased by the year 2000 to 2.7 in the high series, was held constant to the year 2000 at the 1975 level in the medium series, and was assumed to have declined by the year 2000 to 1.9 in the low series. The rates in the year 2000 are those assumed by the Foreign Demographic Analysis Division, U.S. Bureau of the Census (U.S. Department of Commerce, 1976) and are generally based on official projections of the countries of Eastern Europe.

FIGURE B-20.
Total Fertility Rates for Eastern Europe: Estimated 1960-75 and Projected 1975-2000



The total fertility rate in Western Europe of 2.0 in 1975 was assumed to have increased to 2.4 by the year 2000 in the high series, 2.2 in the medium series, and to have decreased slightly below 2.0 in the low series. The rates in the year 2000 and for the intervening years generally follow the trend of the fertility rate in the countries of Western Europe in the U.N. projections (United Nations, 1975). The United Nations fertility assumptions were based generally on official projections of the individual countries of Europe.

FIGURE B-21.
Total Fertility Rates for Western Europe: Estimated 1960-75 and Projected 1975-2000



Mortality. In all series, life expectancy at birth for Eastern Europe was assumed to increase from 67 years to 71 years for males and from 72 years to 75 years for females between 1975 and 2000. In Western Europe, the increase in the same time period was assumed to be from 69 years to 72 years for males and from 75 years to 77 years for females. The life expectancies in all series are those assumed for European countries by the United Nations in the medium-variant projections (United Nations, 1975).

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Coale, Ansley J. and Paul Demeny. 1966. **Regional Model Life Tables and Stable Populations.** Princeton University Press, Princeton.

Princeton University, Office of Population Research. **Population Index.** 1977. Vol. 43, No. 2. Princeton.

United Nations. Various dates. **Population and Vital Statistics Report.** Quarterly. New York.

__________. 1975. **Selected World Demographic Indicators By Countries, 1950-2000.** ESA/P/WP/.55. New York.

__________. 1976a. Paper containing model age patterns of fertility (age-specific fertility rates) for given levels of gross reproduction rates by regions of the world. Computer printout, unpublished.

__________. 1976b. **Population By Sex and Age For Regions and Countries, 1950-2000, As Assessed In 1973: Medium Variant.** ESA/P/WP.60. New York.

__________. 1977. **World Population Prospects as Assessed in 1973.** Population Studies, No. 60. New York.

U.S. Department of Commerce, Foreign Demographic Analysis Division. 1976. **Projections of the Populations of the Communist Countries of Eastern Europe, by Age and Sex: 1975 to 2000,** by Godfrey Baldwin. P-91, No. 25. Washington, D.C.

REMAINDER OF CONTINENTS

Component projections were prepared for the "remainder" of continents, excluding the countries for which individual projections were made. Therefore, projections were made for the remainder of Africa (excluding Egypt and Nigeria), of Latin America (excluding Brazil, Mexico, and Temperate South America), and for the remainder of Asia and Oceania combined (excluding the developed countries of Oceania and the selected Asian countries studied in this report).

Base Data

Base date: July 1, 1975

Population. Estimates of base-year populations for the three remainders of continents were made as follows: (1) medium-variant U.N. projections for 1975 (United Nations, 1976b) were used to determine an age-sex distribution for a particular "remainder" by subtracting from the continental population the populations of countries in that continent for which separate projections are provided in this report, and (2) the age-sex distribution pattern of the U.N. remainder population was applied to a more recent Census Bureau estimate of the aggregate remainder population (U.S. Bureau of the Census, 1976).

Fertility level. Three levels of the 1975 total fertility rates for each of the three remainders of continents were derived from the estimated fertility rates for appropriate countries in the United Nations high, medium, and low variants, respectively (United Nations, 1975) weighted by 1975 United Nations population estimates.[7]

Age-specific rates for 1975 were derived from U.N. model age patterns for appropriate regions at equivalent levels of fertility (United Nations, 1977, pp. 7-11 and United Nations, 1976a).

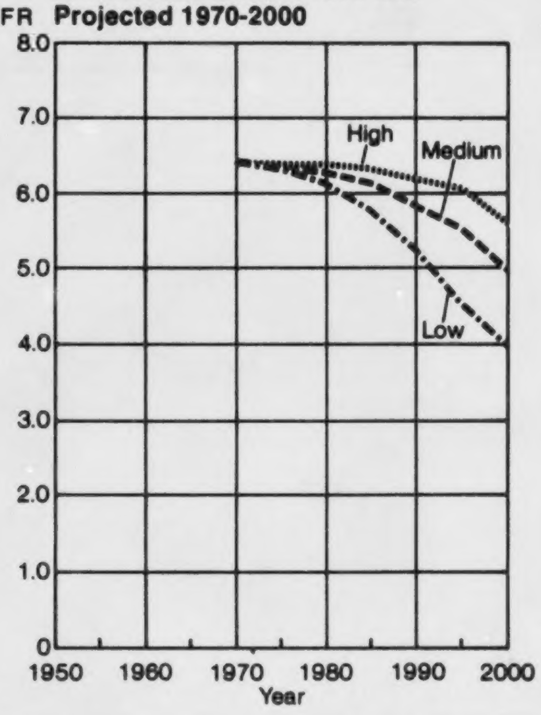
Mortality levels. For the base-year life expectancy, the United Nations medium-variant projections of life expectancies for the 1970-75 and 1975-80 periods, for individual countries appropriate to each remainder of continent, were averaged and weighted by the populations as shown in the United Nations medium variant (United Nations, 1975). Coale-Demeny south region model life tables (Coale and Demeny, 1966) at an equivalent level of life expectancy, by sex, were assumed to represent the pattern of mortality.

Projection Assumptions

Fertility. The assumed total fertility rates for the three remainders of continents for the years 1975 and 2000 are as follows:

Area	Series	Total fertility rate (per woman) 1975	2000
Remainder of Africa . . .	High	6.4	5.6
	Medium	6.3	5.0
	Low	6.3	4.0
Remainder of Asia and Oceania	High	5.6	4.2
	Medium	5.4	3.6
	Low	5.3	3.2
Remainder of Latin America.	High	5.2	4.3
	Medium	5.1	3.4
	Low	5.0	2.5

FIGURE B-22.
Total Fertility Rates for Remainder of Africa: Estimated 1970 and Projected 1970-2000



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[7] Adjustments were made for the "Remainder of Latin America" on the basis of recent fertility data for Colombia.

The fertility rates in the year 2000 and for intervening years between 1975 and 2000 are approximately those implied by trends in the total fertility rate for the appropriate countries between the 1970-75 and 1995-2000 periods in the United Nations high-, medium-, and low-projection series (United Nations, 1975).

Mortality. The assumed life expectancies at birth for the three remainders of continents for the years 1975 and 2000 are as follows:

Area	Sex	Life expectancy at birth (in years) 1975	2000
Remainder of Africa . . .	Male	44	56
	Female	48	59
Remainder of Asia and Oceania	Male	47	59
	Female	49	62
Remainder of Latin America.	Male	58	69
	Female	61	72

The mortality assumption is the same for the high, medium, and low series for all three remainders.

The life expectancies used in this report are those assumed for the appropriate countries by the United Nations in the medium-variant projections (United Nations, 1975). The period values for the intervening years are approximately those implied by trends in the life expectancy between the 1970-75 and 1995-2000.

Migration. No international migration was assumed to have occurred during the projection period.

Major Sources

Coale, Ansley J. and Paul Demeny. 1966. **Regional Model Life Tables and Stable Populations.** Princeton University Press, Princeton.

United Nations. 1975. **Selected World Demographic Indicators By Countries, 1950-2000.** ESA/P/WP.55. New York.

_________. 1976a. Paper containing model age patterns of fertility (age-specific fertility rates) for given levels of gross reproduction rates by regions of the world. Computer printout, unpublished.

_________. 1976b. **Population By Sex and Age For Regions and Countries, 1950-2000, As Assessed In 1973: Medium Variant.** ESA/P/WP.60. New York.

_________. 1977. **World Population Prospects as Assessed in 1973.** Population Studies, No. 60. New York.

U.S. Bureau of the Census, International Statistical Programs Center. 1976. **World Population: 1975-Recent Demographic Estimates for the Countries and Regions of the World.** ISP-WP-75. Washington, D.C.

FIGURE B-23.
Total Fertility Rates for Remainder of Asia and Oceania: Projected 1970-2000

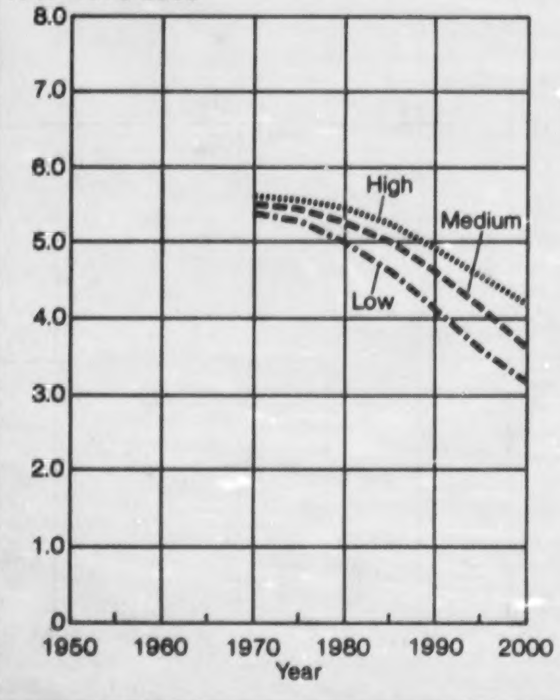
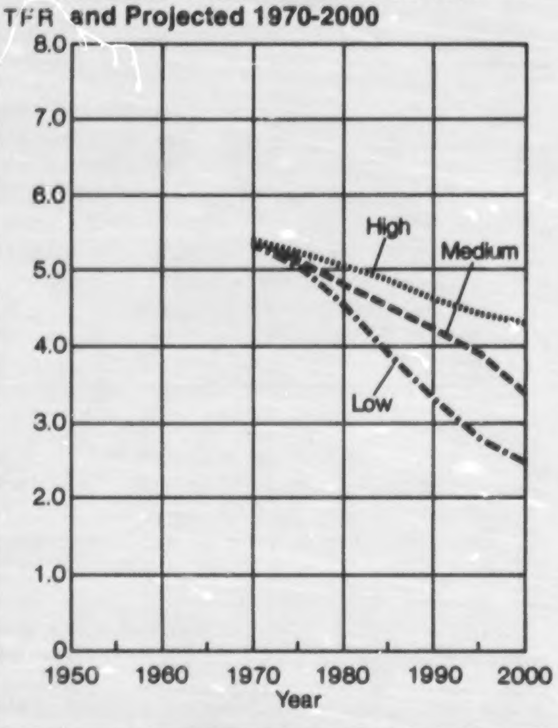


FIGURE B-24.
Total Fertility Rates for Remainder of Latin America: Estimated 1970 and Projected 1970-2000



UNITED STATES DEPARTMENT OF COMMERCE
Bureau of the Census
Washington, D.C. 20233

December 15, 1977

Editor's note: This memorandum was provided to the Global 2000 Study Director by the Bureau of the Census in response to questions about consistency between mortality assumptions in the population projections and the food projections.

MEMORANDUM FOR Dr. Gerald Barney
Study Director, Global 2000 Project

From: Larry Heligman and Samuel Baum
Population Division, Bureau of the Census

Subject: Consistency between mortality assumptions in population projections and food projections

Levels and trends in mortality over time are related to many factors, including for example, quantity and quality of food and housing, degree of economic pressures, availability of medical knowledge, personnel and supplies, and the extent of public health programs. The mortality assumptions built into the population projections implicitly assume moderate technological progress in our ability to make these mortality-reducing factors available and various degrees of progress in the diffusion of these factors among all segments of the populations of the developing world.

Countries, such as many of those in Africa, which are at relatively low levels of food, housing, economic development, medicine and public health, and so forth (especially at low levels of factors such as public health programs which are relatively cheap and easy to apply) are assumed in the population projections to show the most progress in reducing mortality, as the diffusion of the existing and easily transferable technologies takes place. Other countries, such as many in Latin America, where the inexpensive and easy to apply methods of death control have already been implanted among large segments of the population, and where future improvements in mortality will depend largely upon factors much more expensive and difficult to implement (such as the raising of nutrition levels among the large poorly-fed segment of the population), smaller progress in reducing mortality is expected to be made.

None of this is inconsistent with the food projections, as food is only one component of the many which determine levels and trends in mortality. For example, Africa and Latin America are both projected to have relatively small progress in food consumption per capita (about 0.4% annually) but Africa is assumed to have a much more rapid improvement in mortality. Life expectancy in Africa is assumed to increase by 0.9% per year; whereas, life expectancy in Latin America is assumed to increase by only 0.4 percent per year. Given the different levels of life expectancy at the beginning of the projection period in the two regions (46 years in Africa and 63 years in Latin America), and the different levels and mixes of mortality-reducing factors in the two regions (as mentioned in the previous paragraph), the different pace of projected mortality decline in the two regions, even in the face of equal expansion of food consumption, is not surprising and certainly not inconsistent.

In summary, we can not find anything inconsistent between the food projections and the mortality assumptions in the population projection. In fact, given the large number of factors in addition to food consumption which determine levels and trends in mortality, it would be difficult to argue that any reasonable set of food projections are inconsistent with the mortality assumptions.

UNITED STATES DEPARTMENT OF COMMERCE
Bureau of the Census
Washington, D.C. 20233

Editor's note: This material was provided by the Bureau of the Census in response to a request for projections to the year 2100 with age-specific fertility and mortality rates kept constant at the levels reached in the year 2000 in the Global 2000 projections, middle series.

February 26, 1980

Dr. Jerry Barney
Council on Environmental Quality
722 Jackson Place, N.W.
Washington, D.C. 20006

Dear Jerry:

Enclosed is a summary table showing the results of projections to the year 2100, with fertility (age-specific fertility rates) and mortality (age-specific mortality rates) kept constant at the level reached in the year 2000 in the Global 2000 projections middle series. The more developed and the less developed areas (as defined for the Illustrative Projections report) were projected separately, with a TFR of 2.2 children per woman for more developed areas, male life expectancy of 69.8 years, and female life expectancy of 77.0 years; and with a TFR of 3.6 children per woman for less developed areas, male life expectancy of 61.9 years, and female life expectancy of 65.1 years.

You will note that the changes in age composition result in a reduction in the growth rates for both more and less developed regions until the period 2030-2035, but that after 2070, the increasing weight of the less developed regions causes the World growth rate to increase even though the more developed and less developed regions' growth rates remain constant.

Looking forward to seeing the final version of Global 2000, as I am sure you are also. Best regards,

Sincerely,

SAMUEL BAUM
Chief, International
  Demographic Data Center
Bureau of the Census

Enclosure

2/25/80

Projections of World Population to the Year 2100 Assuming Constant (Year 2000) Fertility and Mortality Rates

	Total population at beginning of period (in billions)				Average Annual Growth Rate (in percent)		
Period	World	More Developed	Less Developed	LDC percent of World	World	More Developed	Less Developed
2000 - 2005	6.4	1.3	5.0	79	1.6	0.4	1.9
2005 - 2010	6.9	1.4	5.5	80	1.6	0.4	1.8
2010 - 2015	7.4	1.4	6.1	81	1.5	0.4	1.8
2015 - 2020	8.0	1.4	6.6	82	1.5	0.4	1.7
2020 - 2025	8.7	1.4	7.2	83	1.5	0.3	1.7
2025 - 2030	9.3	1.5	7.9	84	1.4	0.3	1.7
2030 - 2035	10.0	1.5	8.6	85	1.4	0.2	1.6
2035 - 2040	10.8	1.5	9.3	86	1.4	0.2	1.6
2040 - 2045	11.6	1.5	10.1	87	1.4	0.2	1.6
2045 - 2050	12.4	1.5	10.9	88	1.4	0.2	1.6
2050 - 2055	13.3	1.5	11.8	88	1.4	0.2	1.6
2055 - 2060	14.3	1.6	12.7	89	1.4	0.2	1.6
2060 - 2065	15.4	1.6	13.8	90	1.4	0.2	1.6
2065 - 2070	16.5	1.6	14.9	90	1.4	0.2	1.6
2070 - 2075	17.7	1.6	16.1	91	1.5	0.2	1.6
2075 - 2080	19.1	1.6	17.4	91	1.5	0.2	1.6
2080 - 2085	20.5	1.7	18.9	92	1.5	0.2	1.6
2085 - 2090	22.1	1.7	20.4	92	1.5	0.2	1.6
2090 - 2095	23.8	1.7	22.1	93	1.5	0.2	1.6
2095 - 2100	25.6	1.7	23.9	93	1.5	0.2	1.6
2100	27.6	1.7	25.8	94	1.5	0.2	1.6

UNITED STATES DEPARTMENT OF COMMERCE
Bureau of the Census
Washington, D.C. 20233

Editor's note: This material was provided by the Bureau of the Census following some ongoing updating of data on selected countries.

May 15, 1978

Dr. Jerry Barney
Council on Environmental
Quality
722 Jackson Place, N.W.
Washington, D.C. 20006

Dear Jerry:

As we discussed on the phone, we strongly recommend that some mention of the new figures for Chine be made in the Global 2000 report. The attached paragraph is a suggested footnote to the section discussing the Census Bureau population projections.

Sincerely,

SAMUEL BAUM
Assistant Chief for International
Demographic Statistics
Population Division
Bureau of the Census

Enclosure

Since the preparation of the Global 2000 projections, the Census Bureau has revised their estimates for some countries (see U.S. Bureau of the Census, World Population: 1977, forthcoming). The magnitude of these changes has generally been small. However, substantial revision of the estimates have been made for the People's Republic of China. For a full discussion of the new China figures, see John S. Aird, "Population Growth in the People's Republic of China", in Joint Economic Committee, Congress of the United States, Chinese Economy Post Mao, Volume 1, forthcoming, U.S. Government Printing Office, Washington, D.C., 1978. The following table shows the effect of these changes on the world population totals.

Effect of Revised Estimates of the Population of the People's Republic of China on the Census Bureau Global 2000 Population Projections

(Population figures in millions)

	World	Less Developed Countries	People's Republic of China
MEDIUM SERIES			
1975			
Using Old China Estimates	4,090	2,959	935
Using Revised China Estimates	4,098	2,967	943
2000			
Using Old China Estimates	6,350	5,027	1,329
Using Revised China Estimates	6,401	5,078	1,380
HIGH SERIES			
1975			
Using Old China Estimates	4,134	3,003	978
Using Revised China Estimates	4,124	2,993	968
2000			
Using Old China Estimates	6,797	5,419	1,468
Using Revised China Estimates	6,817	5,439	1,488
LOW SERIES			
1975			
Using Old China Estimates	4,043	2,912	889
Using Revised China Estimates	4,069	2,938	915
2000			
Using Old China Estimates	5,921	4,647	1,176
Using Revised China Estimates	6,000	4,726	1,255

Editor's note: This table was transmitted from Dr. Samuel Baum, U.S. Bureau of the Census, to Dr. Gerald Barney, Global 2000 Study Director, on April 9, 1980.

3/28/80

Population for World, Major Regions and Selected Countries in the Year 2000 as Prepared for the Global 2000 Report and as Revised by Substitution of New Projections for Eight Countries

(Population in millions)

Region and countries	High Series			Medium Series			Low Series		
	As prepared for Global 2000 Report	As revised by substitution of new projections	Difference	As prepared for Global 2000 Report	As revised by substitution of new projections	Difference	As prepared for Global 2000 Report	As revised by substitution of new projections	Difference
WORLD	6,797	6,520	-277	6,350	6,175	-175	5,921	5,799	-122
More Developed	1,377	1,377	0	1,323	1,323	0	1,274	1,274	0
Less Developed	5,420	5,420	-277	5,027	4,852	-175	4,647	4,525	-122
Less Developed minus Mainland China	3,952	3,952	-234	3,698	3,568	-130	3,471	3,384	-87
Mainland China	1,468	1,425	-43	1,329	1,284	-45	1,176	1,141	-35
India	1,142	995	-147	1,021	959	-62	974	922	-52
Indonesia	236	230	-6	226	224	-2	209	220	11
Thailand	81	78	-3	75	72	-3	69	66	-3
Korea, Republic of	62	61	-1	57	56	-1	54	54	0
Pakistan	156	156	0	149	152	3	144	147	3
Brazil	241	198	-43	226	190	-36	214	183	-31
Mexico	141	107	-34	131	102	-29	110	96	-14
SUM of 8 countries shown	3,526	3,250	-276	3,214	3,039	-175	2,950	2,828	-122

NOTE: The new projections for the eight countries do not take into account international migration as was the case for all the countries included in the Global 2000 report.

Editor's note: Following are several tables and charts prepared by the Bureau of the Census. They compare the assumptions made by the Bureau of the Census and the Community and Family Study Center (University of Chicago) in developing the Global 2000 projections. In general, the Community and Family Study Center's assumptions reflect a conviction that public policy around the world will soon shift in the direction of much stronger family planning programs and that family planning programs will be effective in reducing fertility rates quickly.

Comparison Between U.S. Bureau of the Census and University of Chicago Data on Total Fertility Rates, 1970 to 2000

		Total Fertility Rates				Percent of difference[1]		Absolute difference[2]	Percent Change 1975-2000[3]	
		1975		2000						
Area and series		Census	Chicago	Census	Chicago	1975	2000	1975	Census	Chicago
World	High	4.5299	NA	3.9189	NA	NA	NA	NA	-13.5	NA
	Medium	4.2654	NA	3.3098	NA	NA	NA	NA	-22.4	NA
	Low	3.9942	NA	2.7546	NA	NA	NA	NA	-31.0	NA
Africa	High	6.3847	5.2800	5.6424	3.7630	+17.3	+33.3	+1.1047	-11.6	-28.7
	Medium	6.3524	5.2800	5.0156	3.5355	+16.9	+29.5	+1.0724	-21.0	-33.0
	Low	6.3146	5.2800	4.0436	3.2460	+16.4	+19.7	+1.0346	-36.0	-38.5
Asia and Oceania	High	5.3501	4.2015	3.8829	2.0005	+21.5	+48.5	+1.1486	-27.4	-52.4
	Medium	4.8865	4.2015	3.2238	2.0005	+14.0	+37.9	+0.8650	-34.0	-52.4
	Low	4.4170	4.2015	2.7163	1.9000	+ 4.9	+30.1	+0.21550	-38.5	-54.8
Latin America	High	5.3992	4.4225	4.4952	2.5475	+18.1	+43.3	+0.9767	-16.7	-42.4
	Medium	5.2679	4.4225	3.6391	2.9145	+16.0	+19.9	+0.8454	-30.9	-34.1
	Low	5.1030	4.4225	2.8949	1.8285	+13.3	+36.8	+0.6805	-43.3	-58.7
U.S.S.R. and Eastern Europe	High	2.3700	2.4840	2.6719	1.9995	- 4.8	+25.2	-0.1140	+12.7	-19.5
	Medium	2.3700	2.4840	2.2659	1.8995	- 4.8	+16.2	-0.1140	- 4.4	-23.5
	Low	2.3700	2.4840	1.8620	1.8000	- 4.8	+ 3.3	-0.1140	-21.4	-27.5
Northern America, Western Europe, Japan, Australia, and New Zealand	High	1.9703	NA	2.5328	NA	NA	NA	NA	+28.5	NA
	Medium	1.9697	NA	2.1751	NA	NA	NA	NA	+10.4	NA
	Low	1.9695	NA	1.8559	NA	NA	NA	NA	- 5.8	NA
Selected Countries and Regions										
People's Republic of China	High	5.1710	3.1995	3.0750	2.0000	+38.1	+35.0	+1.9815	-40.5	-37.5
	Medium	4.1280	3.1995	2.5620	1.8990	+22.5	+25.9	+0.9285	-37.9	-40.6
	Low	3.0830	3.1995	2.0500	1.7995	- 3.8	+12.2	-0.1165	-33.5	-43.8
India	High	5.3000	5.4985	4.5000	3.2055	- 3.7	+28.8	-0.1985	-15.1	-41.7
	Medium	5.3000	5.4985	3.4999	2.8860	- 3.7	+17.5	-0.1985	-34.0	-47.5
	Low	5.3000	5.4985	3.0000	2.4705	- 3.7	+17.7	-0.1985	-43.4	-55.1

Comparison between U.S. Bureau of the Census and University of Chicago Data on Total Fertility Rates, 1970 to 2000 (continued)

		Total Fertility Rates				Percent of difference[1]		Absolute difference[2]	Percent Change 1975-2000[3]	
		1975		2000						
Area and series		Census	Chicago	Census	Chicago	1975	2000	1975	Census	Chicago
Indonesia	High	5.3235	5.1185	4.0000	2.3325	+ 3.9	+41.7	+0.2050	-24.9	-54.4
	Medium	5.3235	5.1185	3.5000	2.3325	+ 3.9	+33.4	+0.2050	-34.3	-54.4
	Low	5.3235	5.1185	2.4995	1.8985	+ 3.9	+24.0	+0.2050	-53.0	-62.9
Bangladesh	High	6.9999	6.5780	5.0000	4.5035	+ 6.0	+ 9.9	+0.4219	-28.6	-31.5
	Medium	6.9999	6.5780	4.2500	4.0865	+ 6.0	+ 3.8	+0.4219	-39.3	-37.9
	Low	6.9999	6.5780	3.5000	3.4110	+ 6.0	+ 2.5	+0.4219	-50.0	-48.1
Pakistan	High	6.9000	6.2650	5.0000	4.1695	+ 9.2	+16.6	+0.6350	-27.5	-33.4
	Medium	6.9000	6.2650	4.2500	3.5830	+ 9.2	+15.7	+0.6350	-38.4	-42.8
	Low	6.9000	6.2650	3.5000	3.0535	+ 9.2	+12.8	+0.6350	-49.3	-51.3
Philippines	High	5.3995	5.5050	3.7995	2.5265	- 2.0	+33.5	-0.1055	-29.6	-54.1
	Medium	5.0705	5.5050	3.1995	2.5265	- 8.6	+21.0	-0.4345	-36.9	-54.1
	Low	4.7995	5.5050	2.5000	2.0375	-14.7	+18.5	-0.7050	-47.9	-63.0
Thailand	High	5.1675	4.8500	3.9000	2.0360	+ 6.1	+47.8	+0.3175	-24.5	-58.0
	Medium	5.0500	4.8500	3.1000	2.0360	+ 4.0	+34.3	+0.2000	-38.6	-58.0
	Low	4.9000	4.8500	2.4000	1.8000	+ 1.0	+25.0	+0.0500	-51.0	-62.9
South Korea	High	3.9251	3.5805	3.1000	1.9000	+ 8.8	+38.7	+0.3446	-21.0	-46.9
	Medium	3.7889	3.5805	2.5000	1.9000	+ 5.5	+24.0	+0.2084	-34.0	-46.9
	Low	3.4099	3.5805	2.1275	1.8000	- 5.0	-15.4	-0.1706	-37.6	-49.7
Egypt	High	5.8190	5.2095	4.6001	2.9855	+10.5	+35.1	+0.6095	-20.9	-42.7
	Medium	5.8190	5.2095	3.6000	2.5955	+10.5	+27.9	+0.6095	-38.1	-50.2
	Low	5.8190	5.2095	2.6000	2.1820	+10.5	+16.1	+0.6095	-55.3	-58.1
Nigeria	High	6.6999	6.6995	6.3750	5.7610	same	+ 9.6	same	- 4.8	-14.0
	Medium	6.7000	6.6995	5.9000	4.7905	same	+18.8	same	-11.9	-28.5
	Low	6.6999	6.6995	4.9999	4.4995	same	same	same	-25.4	-32.8
Brazil	High	5.7800	5.1495	5.0000	2.9370	+10.9	+41.3	+0.6305	-13.5	-43.0
	Medium	5.7255	5.1495	3.9995	2.5370	+10.1	+36.6	+0.5760	-30.1	-50.7
	Low	5.5500	5.1495	3.5000	2.1215	+ 7.2	+39.4	+0.4005	-36.9	-58.8

Comparison between U.S. Bureau of the Census and University of Chicago Data on Total Fertility Rates, 1970 to 2000 (continued)

Area and series		Total Fertility Rates 1975 Census	Total Fertility Rates 1975 Chicago	Total Fertility Rates 2000 Census	Total Fertility Rates 2000 Chicago	Percent of difference[1] 1975	Percent of difference[1] 2000	Absolute difference[2] 1975	Percent Change 1975-2000[3] Census	Percent Change 1975-2000[3] Chicago
Mexico	High	6.7005	6.1330	4.7000	3.9560	+ 8.5	+15.8	+0.5675	-29.9	-35.5
	Medium	6.3600	6.1330	4.0005	3.4290	+ 3.6	+14.3	+0.2270	-37.1	-44.1
	Low	5.9120	6.1330	3.0000	2.8975	- 3.7	+ 3.4	-0.2210	-49.3	-52.8
United States	High	1.7705	1.8175	2.6890	2.0210	- 2.7	+24.8	-0.0470	+51.9	+11.2
	Medium	1.7705	1.8175	2.0955	1.9190	- 2.7	+ 8.4	-0.0470	+18.4	+ 5.6
	Low	1.7705	1.8175	1.6935	1.8185	- 2.7	- 7.4	-0.0470	- 4.3	constant
USSR	High	2.4055	2.4165	2.6610	2.0270	- 0.5	+23.8	-0.0110	+10.6	-16.1
	Medium	2.4055	2.4165	2.2575	1.8990	- 0.5	+15.9	-0.1100	- 6.2	-21.4
	Low	2.4055	2.4165	1.8540	1.8010	- 0.5	+ 2.9	-0.1100	-22.9	-25.5
Japan	High	1.9245	2.1590	2.3000	2.0000	-12.2	+13.0	-0.2345	+19.5	- 7.4
	Medium	1.9245	2.1590	2.1000	1.8995	-12.2	+ 9.5	-0.2345	+ 9.1	-12.0
	Low	1.9245	2.1590	1.8000	1.7995	-12.2	same	-0.2344	- 6.5	-16.7
Eastern Europe	High	2.2700	NA	2.6800	NA	NA	NA	NA	+18.1	NA
	Medium	2.2700	NA	2.2699	NA	NA	NA	NA	constant	NA
	Low	2.2700	NA	1.8700	NA	NA	NA	NA	-17.6	NA
Western Europe	High	2.0220	2.2045	2.4199	2.0000	- 9.0	+17.4	-0.1825	+19.7	- 9.3
	Medium	2.0220	2.2045	2.2070	1.9000	- 9.0	+13.9	-0.1825	+ 9.1	-13.8
	Low	2.0220	2.2045	1.9590	1.7995	- 9.0	+ 8.1	-0.1825	- 3.1	-18.4

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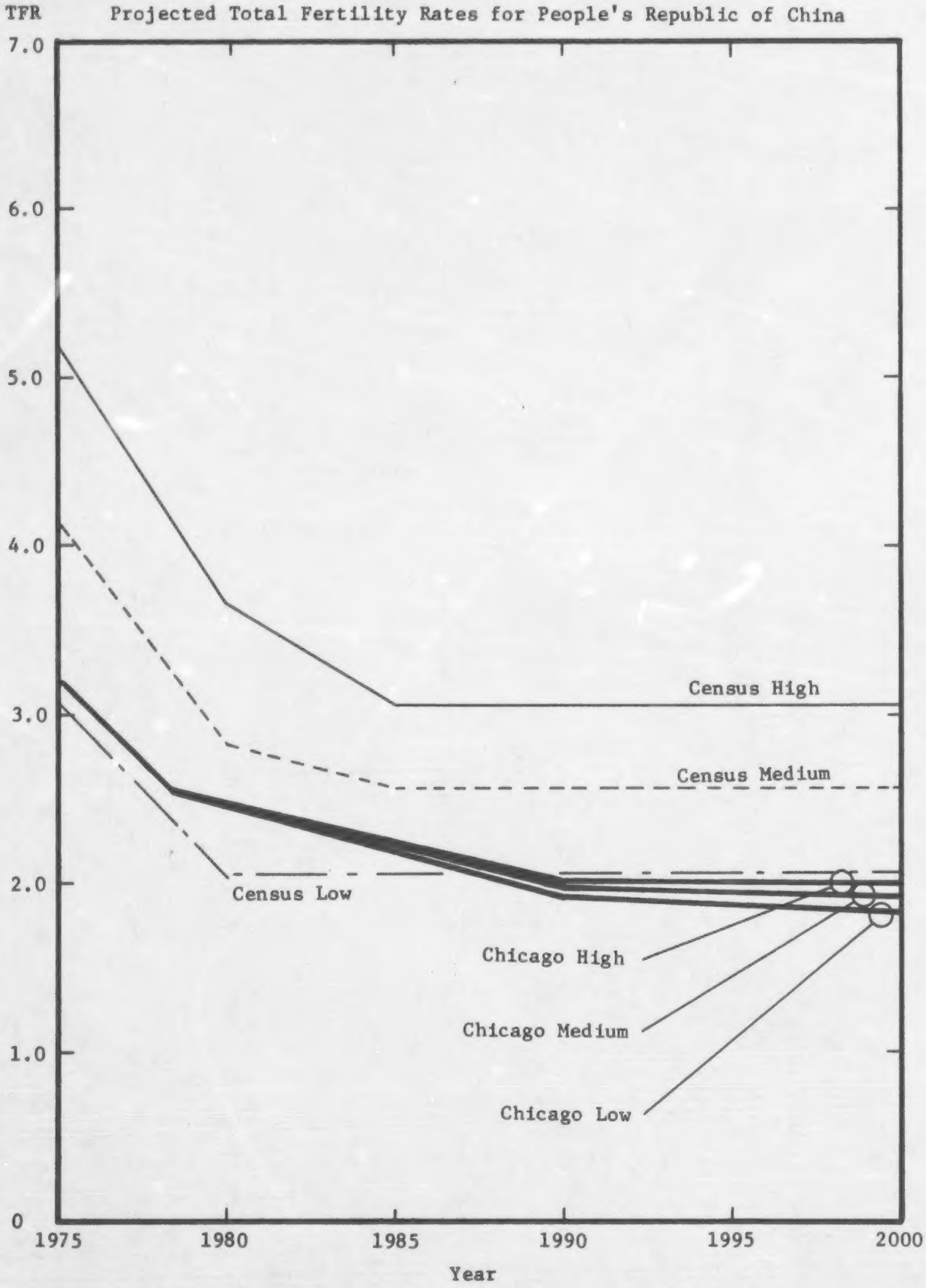
[1] Calculated at U.S. Bureau of the Census: $\frac{\text{Census figure - Chicago figure}}{\text{Census figure}} \times 100 =$ percent difference.

[2] Calculated at U.S. Bureau of the Census: Census figure - Chicago figure = absolute difference.

[3] Calculated at U.S. Bureau of the Census: $\frac{\text{2000 figure - 1975 figure}}{\text{1975 figure}} \times 100 =$ percent change 1975-2000

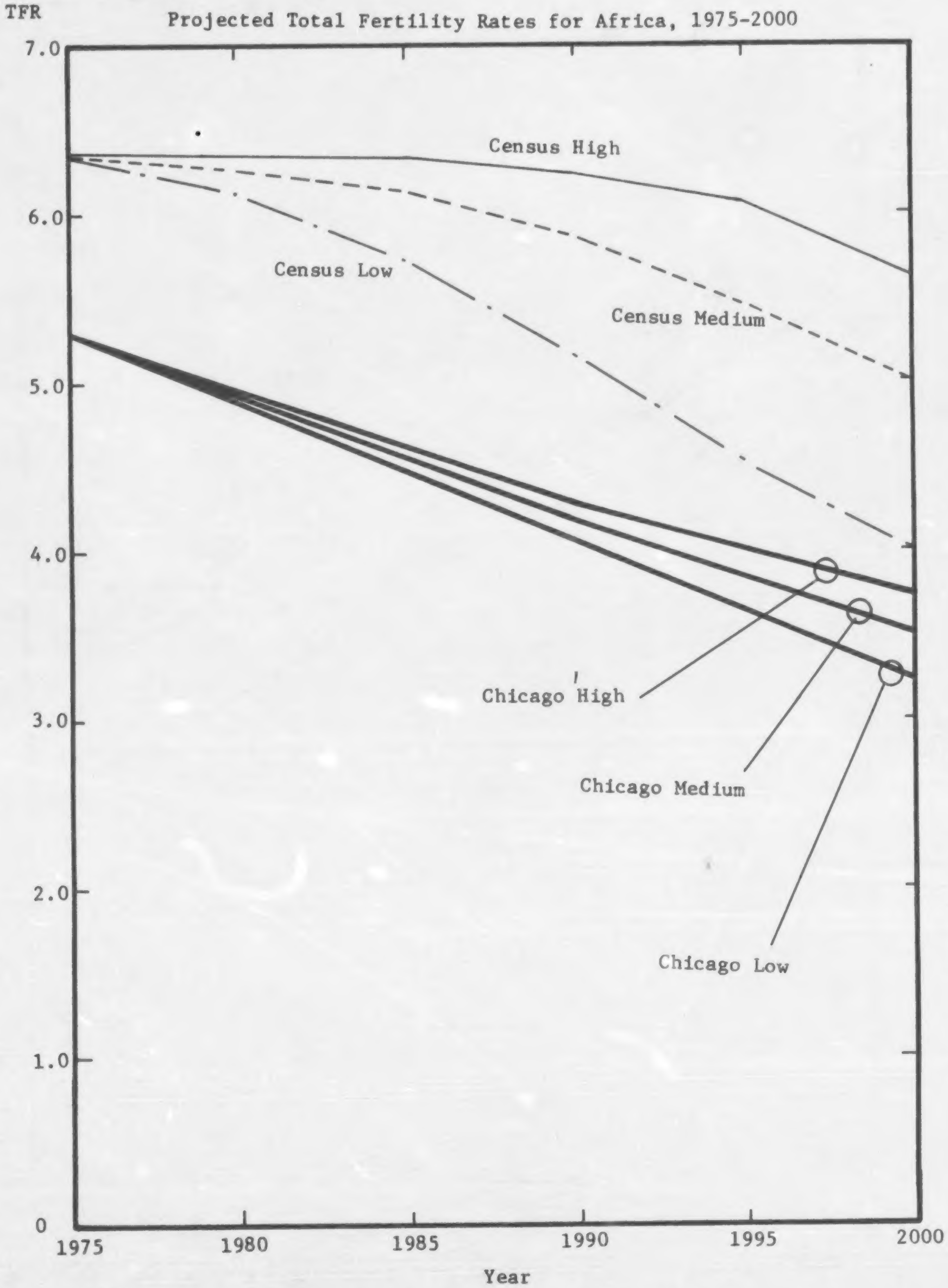
Source: U.S. Bureau of the Census and University of Chicago printouts for World Projections, October 13, 1977.

Projected Total Fertility Rates for People's Republic of China



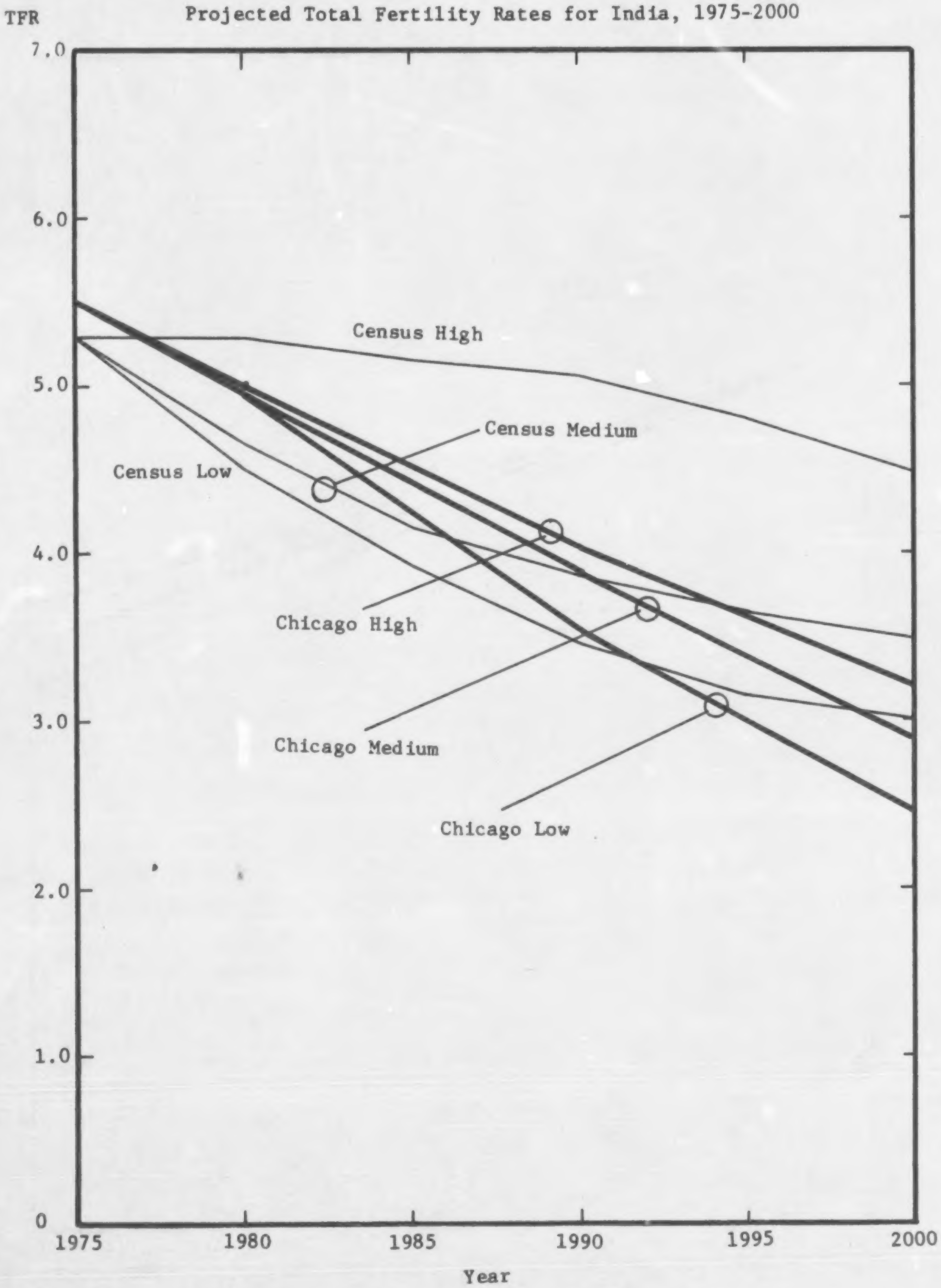
Source: U.S. Bureau of the Census, Foreign Demographic Analysis Branch.

Projected Total Fertility Rates for Africa, 1975-2000



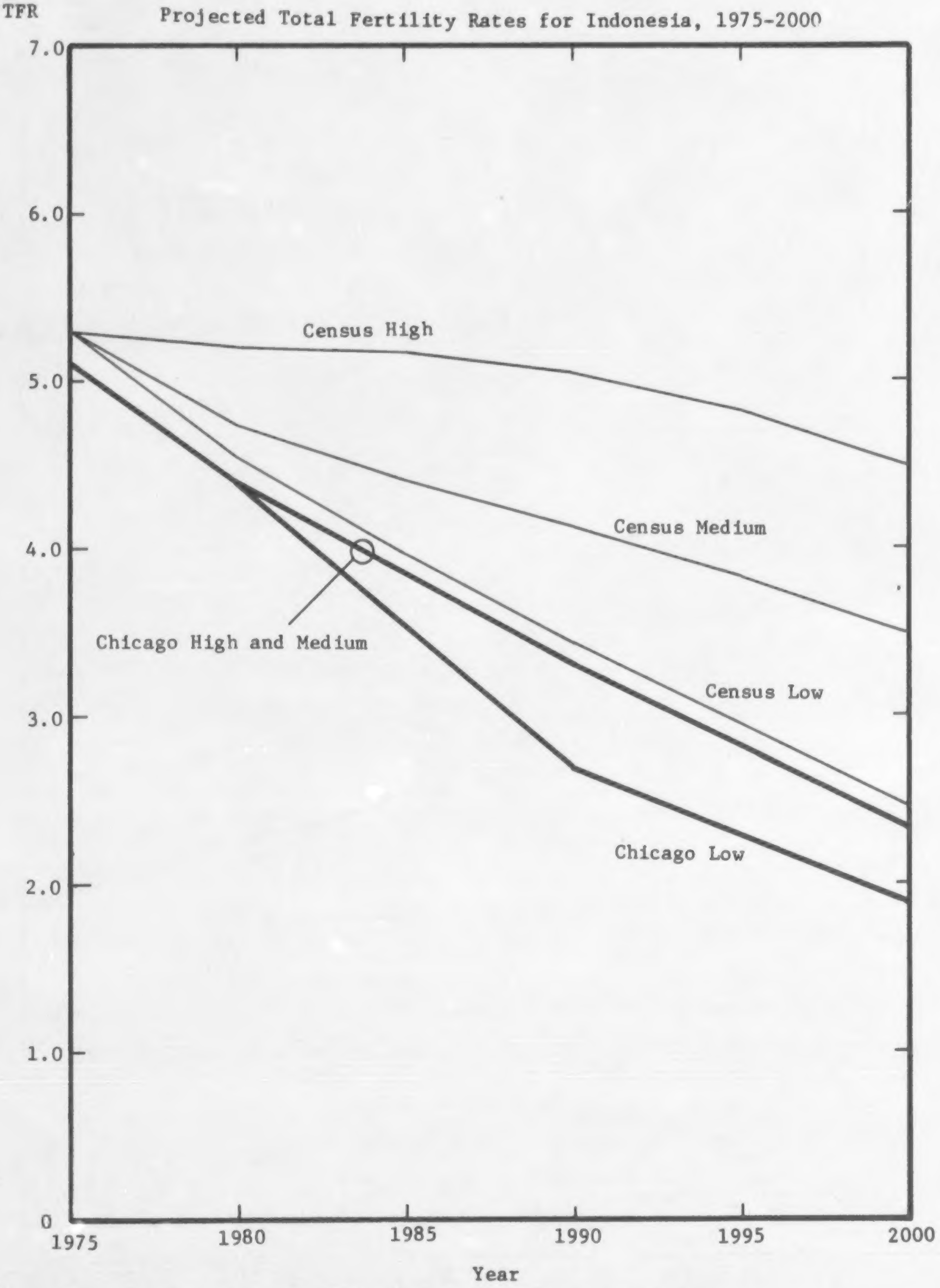
Source: U.S. Bureau of the Census, Population Division

Projected Total Fertility Rates for India, 1975-2000

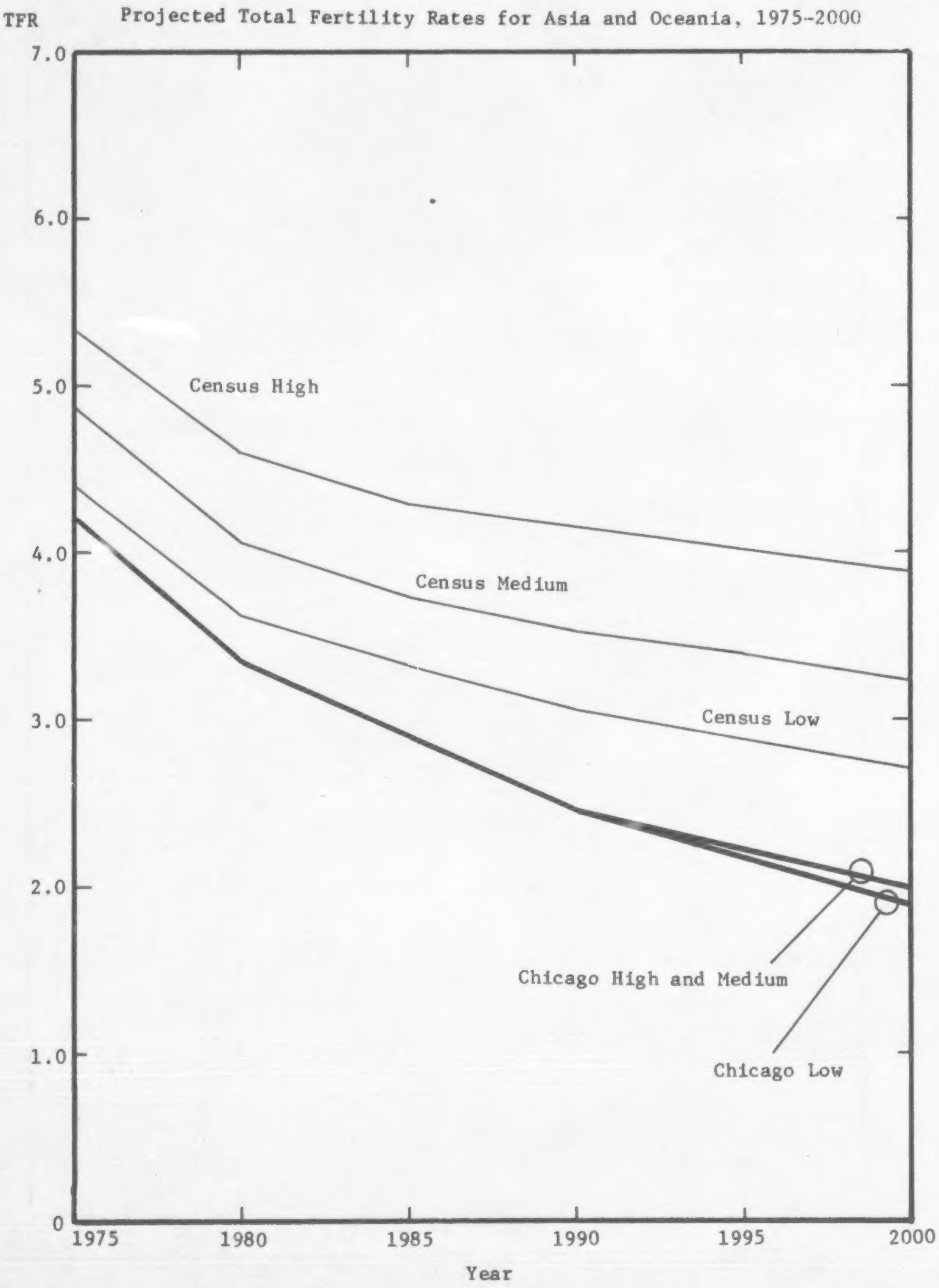


Source: U. S. Bureau of the Census, Population Division

Projected Total Fertility Rates for Indonesia, 1975-2000



Source: U.S. Bureau of the Census, Population Division



Source: U.S. Bureau of the Census, Population Division

2 The Population Sector
(Agency for International Development/Community and Family Study Center)

Introduction

As was noted in the introduction to Chapter 1, the Population Office of the U.S. Agency for International Development (AID) requested that the Global 2000 Study include not only projections by the U.S. Bureau of the Census, but also projections by the Community and Family Study Center (CFSC) at the University of Chicago. AID was interested in including the CFSC projections because they are based on a model that assumes the rapid introduction of family planning programs throughout the world and assumes that family planning programs will be highly effective in reducing fertility rates. While the CFSC projections thus strongly violate the basic policy assumption of the Global 2000 Study—continuation of present policies*—they were included as an indication of what might be expected from policy changes that strongly favored family planning programs around the world.

Only a limited amount of methodological material was available from CFSC at the time the Global 2000 analysis was in progress. The first material available was a paper presented at a meeting in the CFSC offices on September 28, 1977. This paper, which is reproduced here, provides a general statement of the CFSC methodology. Later, the CFSC provided a further, more specific methodological statement, which also is presented here.

After the Global 2000 methodological analysis was completed, Paul Demeny, editor of the *Population and Development Review,* wrote and published a commentary on the CFSC methodology and projections in the March 1979 issue of his journal. A reply by Donald J. Bogue and Amy O. Tsui, the developers of the CFSC methodology, was published later in the same journal, along with a rejoinder by Paul Demeny. These materials are not reprinted here, but readers wanting further information on the CFSC methodology and projections will be interested in this exchange.[1]

Finally, the CFSC prepared a few comparisons between their own projections and those of Census. Dr. Amy O. Tsui provided these comparisons in her letter of October 31, 1977, to Dr. Baum, which is reproduced here. The Census and CFSC methodologies are generally similar, except on the critically important matter of projecting fertility rates. The differences are seen clearly in the CFSC comparisons.

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*The projections by the Bureau of the Census also violate this assumption by anticipating policy shifts favoring more family planning. The Census projections, however, assume a less pronounced increased family planning.

References

1. Paul Demeny, "On the End of the Population Explosion," *Population and Development Review* (New York, Population Council), March 1979, pp. 141–62; Donald J. Bogue and Amy O. Tsui, "A Reply to Paul Demeny's 'On the End of the Population Explosion,'" ibid., May 1979, pp. 479–94; Paul Demeny, "On the End of the Population Explosion: A Rejoinder," ibid., May 1979, pp. 495–504.

Editor's note: This paper was distributed at a meeting in the CFSC offices in Chicago on September 28, 1977.

A PREDICTION OF WORLD FERTILITY TRENDS DURING THE NEXT ONE HUNDRED YEARS

Donald J. Bogue and Amy Tsui
Community and Family Study Center
University of Chicago

I

The Importance of Objectivity in Fertility Prediction

There is no longer much doubt that world fertility trends have taken a sudden and significant turn during the decade 1965 to 1975. Wherever it has become possible to make a factual measurement of fertility change, almost without exception, it has been found that birth rates have fallen during this period. (A few exceptions appear to have occurred in Africa, where declines in mortality and medical corrections for infertility have permitted rises in a fertility that was inexplicably low before.) The full prevalence of these fertility declines, and their magnitude, will be much more measurable as the cycle of census-taking about 1980 to 1981 begins to yield new data. Meanwhile, the results of the World Fertility Survey, occasional censuses, and other surveys are providing an increasingly impressive body of evidence that world birth rates are declining much more rapidly than demographers have dared to expect. This decline appears to be worldwide. The less developed countries are showing dramatic fertility declines, while many developed countries are possibly below replacement levels of fertility with almost unanimous impunity.

It is now quite firmly established by research that the rate of fertility decline in less developed countries is influenced, by more than any other single factor, by the amount and quality of organized family planning programs in the country. Countries which have well-funded programs with nationwide coverage have tended to experience a significantly more rapid decline than nations which have smaller programs or only limited coverage. The full extent of this relationship between family planning efforts and fertility decline is still in the process of study. However, pioneering studies by K.C. Zachariah of the World Bank[1] and Parker Mauldin of the Population Council[2] leave little doubt that the effect is statistically signifant and substantial. Inasmuch as most specialists who are working in the area of family planning programs believe that there are very few, truly well organized programs with full coverage, there are good prospects that the potential effects of family planning programs are substantially greater than those that can be measured with current data.

This discovery, that high fertility is responsive to direct intervention programs, is most heartening to a world that is accustomed to bad news concerning the future of the human race. It would be possible to accept this information in crude form, to dismiss the population explosion as a nightmare that faded with the dawn of modern communication and contraception. To do so would, of course, run the risk of a serious miscalculation of the problems that lie ahead. There is still an urgent need to compute, as carefully as possible, population projections for each individual country and to compare the projected growth trends in that country with its program for social and economic development.

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[1]

[2] Mauldin, W. Parker and Berelson, Bernard. Cross-Cultural Review of the Effectiveness of Family Planning Programs. IUSSP Proceedings, Mexico City, 1977.

Demographers who had long been accustomed to the doctrine of ultimate demographic catastrophe via the Malthusian route have been especially resistant to over-optimism at the revelation of the news concerning fertility decline. They have tended to see each instance as a unique event, caused by a combination of factors that may not occur frequently throughout the world. Even when they admit the influence of family planning programs, they tend to assert that these programs are effective only under certain special circumstances. Following are some examples of hypotheses they have used:

1. The "island or peninsula" hypothesis. According to this hypothesis, fertility declines rapidly only in countries which are comprised of small islands or are peninsulas. Examples are Taiwan, Mauritius, Japan, Indonesia, Singapore, Hong Kong, Malaysia, Costa Rica, etc. Implicit in this hypothesis is the theory that the finite nature of their habitat is much more observable and salient to the residents of such landforms.

2. The racial origins hypothesis. This hypothesis asserts that fertility declines are much more consistent with the culture and philosophy of people with particular racial origins than for other racial groups. For example, populations with oriental origins or influence are supposed to be more responsive to family planning programs. This explains the declines in Japan, Korea, Taiwan, Hong Kong, Singapore, Indonesia, and the comparative slow progress of family planning in Pakistan, Bangladesh, India, and other "brown-skinned" less developed countries. In contrast, the African cultures are supposed to be highly pronatalistic and comparatively impervious to family planning efforts.

3. The economic development hypothesis. It is asserted that fertility decline cannot take place among a population that is at the very bottom of the heap with respect to living standards. Where conditions of life are at the starvation or near-starvation level, it is practically impossible, it is claimed, for family planning programs to have much of an impact. Under such conditions, infant mortality rates tend to be high, traditionalism tends to be rampant, and an atmosphere of fatalistic despair pervades the culture, making it insensitive and unresponsive to the life-saving solution of contraception that is within its grasp. The list of preconditions that are claimed to be necessary before fertility decline can take place is large: maternal and child health care, reduction of infant mortality, improved status for women, improved nutrition, a national social security and retirement system, and others.

4. The education/literacy hypothesis. The segment of the population that practices family planning most faithfully and successfully is that segment which is literate. Especially important is literacy of the wife. Where there is massive illiteracy, family planning programs make small headway because the public cannot get the family planning messages, cannot comprehend them if they do arrive, and lacks the

mental sophistication to carry out the instructions if they are comprehended. At least four years of formal education, and preferably more, are said to be needed to foster rapid fertility decline.

To an objective bystander, this long list of explanations for the recent examples of fertility decline resembles the long list of rationalizations that scientists were making about the behavior of fire until the discovery of oxygen, or about infectious diseases before the discovery of microbes and germs. One begins to suspect that those who present these explanations are so wedded to one particular theory, the Malthusian theory, that they are unable to look dispassionately and objectively at the new body of data that is accumulating about fertility declines.

It would appear that the science of demography has arrived at a critical point in its history. It is confronted with new and unexpected fertility behavior. Instead of clinging desperately to the old Malthusian doctrine which has dominated the discipline for two centuries, rationalizing it with modifications of increasing number and increasing elaborateness, special exceptions and mysterious variables, there is need for a willingness to accept new and simplifying theories.

II

A Theory of Fertility: Post-1965

A theory which explains the recent declines in fertility may be stated as follows:

> When a person becomes convinced that his life conditions can be improved, or saved from becoming worse, by curtailing child-bearing, that person will tend to do so, provided that he achieves:
>
> A. Cognitive preparation
>   1. has the necessary knowledge,
>   2. believes it to be socially acceptable to do so,
>   3. believes that the methods to be used are effective and that the risks of using them are low,
>   4. believes that he is competent to carry out the procedures or that they will work for him.
>
> B. Service
>
> The devices or materials required for contraception are accessible to him, through channels which he trusts and upon which he can rely.

When such a conviction becomes even moderately prevalent among a population and comes to be shared with friends and neighbors, it begins to take on the character of a social movement which then becomes a cultural adaptation.

Stated in aggregate, rather than individual terms, this proposition becomes a sociological theory of demographic regulation which states that every society tends to keep its vital processes in a state of balance such that population will replenish losses from death and grow to an extent deemed desirable by collective norms.

These norms are flexible and readjust rather promptly to changes in the ability of the economy to support a population.

The process described above occurs in the manner of all social changes, and is gradual or rapid depending upon cultural and other characteristics of the group. Although the process may be slower in societies where illiteracy is high, where previous norms have been pronatalist, where there is a fatalistic outlook, where death rates are high, and where economic conditions are low, this demographic regulation can and will eventually take place.

In the absence of external help, the population will gradually evolve its own rationale and procedures. Where conditions are difficult through underdevelopment, the process may be greatly accelerated by providing communications which heighten the saliency of the issue (motivation) and provide cognitive preparation (component A) and service (component B). This theory has significant derivatives or corollaries, as follows:

(a) Where other services are not available, but cognitive preparation is present, a substantial fraction of the population will make use of abortion, infanticide, withdrawal, rhythm or other methods, even though the effectiveness and reliability may not be high.

(b) Where services are provided but where cognitive preparation is low, little change in fertility will take place.

(c) Any program which stimulates cognitive preparation will result in greater demand for the services.

(d) Any program which substitutes highly accessible, reliable, and easy-to-use methods of contraception for unreliable, dangerous, or unpleasant methods will more quickly translate cognitive preparation into actual fertility decline.

(e) Appropriately planned special family planning programs which simultaneously strive to provide the twin components of cognitive preparation and family planning services that are reliable, convenient, and easy-to-use can greatly shorten the length of time required to reduce birth rates.

(f) The pace of fertility decline in the future will depend, in large part, upon the presence or absence of fertility programs, their "quality" (relevance for the existing culture and logistic coverage), and the skill with which they are administered.

III

Assumptions Upon Which to Predict Future Fertility Trends

If the above theory is accepted, the entire process of predicting the future course of human fertility becomes different from that utilized in the past. A simple extrapolation of current fertility rates or recent declines in fertility may result in a great overestimation of future fertility. For the past decade, demographers have consistently underestimated the rate of fertility decline, both in developed and developing countries, with the result that their population projections are quickly shown by the course of events to be too high. Instead of making use of simple extrapolative methods, projections must involve anticipated changes in the quantity and quality of family planning programs and in the expected effectiveness of their efforts. This is the variable which will determine, far more than any other, the course of fertility in the developing nations.

The downward trend in fertility rates in the less developed countries is too recent, and the assessment of the part which family planning programs can play in the future is too crude and inaccurate to permit precise statements of these assumptions. Nevertheless, the need to make population projections is mandatory, and the utilization of such information as is available will yield projections which are an improvement over those made previously.

A proposed set of assumptions for making population projections is as follows:

(a) The process of cognitive preparation is now underway all over the world. it is prevalent implicitly if not explicitly in normal communication, and is being diffused, to some extent, through both the interpersonal and the mass media.

(b) Irrespective of how negative or pronatalistic a nation's position may be today, the fact that high birth rates are highly dysfunctional and contradictory to the achievement of the goals of national development will produce a more permissive if not supportive attitude toward organized family planning programs in the near future. Hence, within a decade, substantial private if not public family planning systems may be expected to be operating everywhere in the world, if they have not already made their appearance.

(c) As the efficacy of family planning in promoting social and economic development becomes more widely appreciated, inputs into this form of international assistance will increase, so that generous aid to any nation permitting it will be available.

(d) Because a large number of professional persons, from many disciplines, are working in the family planning area, and because the volume of research and verified knowledge is now rapidly accumulating, the effectiveness of family planning programs in promoting cognitive preparation will improve greatly. Their ability to work rapidly in low-literacy, low-income, rural, and "backward" situations will improve.

(e) Steady improvement in family planning services (the methods available for use and the quantity and quality of outlets) will be made. This process is already underway in urban centers throughout the world, and may be expected to diffuse rapidly into most rural areas.

Thus, the most realistic assumptions that can be made about the future course of fertility is that in the future birth rates will fall even more rapidly than they have in the recent past in all countries which have high birth rates. In countries where birth rates have not yet begun to decline, this process will begin very shortly. In countries where birth rate declines have already gained momentum, this trend will continue or accelerate. This decline will continue until it reaches levels where population growth and economic well-being have been brought into a socially desirable balance. This may include negative growth.

IV

The Shape of the Fertility Decline Curve

The trend of fertility decline in Europe and the United States tended to be a gentle, almost linear, downward drift over two centuries, with vicissitudes introduced by wars, economic booms, depressions, and internal political upheavals. Although demographers have not discussed this problem yet, most of their population projections assume that the fertility decline curve will be linear; they assume that the trend of fertility in developing countries, once a decline sets in, will also follow a linear path. The usual assumption is that a specified rate of decline will begin at the base date or some future, designated, date and continue at a fixed rate until the terminal date. Both the theory of social change and the empirical evidence from the countries where such declines have taken place suggest that this is an improper assumption.

It is proposed here that the shape of the fertility decline curve during the next century will follow that of a "reverse S" (see Figure 1). This curve has four phases:

(a) Slow takeoff/acceleration,

(b) Rapid mid-period descent toward replacement levels,

(c) Rapid deceleration with a decline to below replacement levels,

(d) Return to replacement levels after a period of below-replacement fertility.

The factors that determine the shape of this curve are not demographic, but sociological. Based on research on the diffusion of many innovations, the process of change can be divided into five periods:

(a) A "pioneer" phase, in which a few daring persons take a risk and adopt.

(b) An "early adopter" phase in which the more sophisticated, more change-oriented individuals join the pioneers in increasing numbers, realizing that the risk is small in comparison with the reward.

(c) A "mass adoption" phase in which the great bulk of the population joins in the adoption, understanding that the risks are small in comparison with the reward.

(d) A "late adopter state" in which the more conservative segment of the society follows the lead of the majority and adopts.

(e) A "laggard" phase, in which the most reactionary, distrustful, and inflexible members gradually conform to what has become a universal practice.

It is believed that the pattern of fertility decline, even more than most innovations, will conform to this sequence. Because adoption of family planning involves both social and medical risks (in the minds of the pioneers and early adopters) it may be expected to have a slow take-off, with increasing acceleration as more people adopt. Once it becomes an accepted, normal activity, the phase of "mass adoption" may be expected. As the supply of potential adopters diminishes and only those who have opposed family planning on extreme religious, political, moral, or unjustified medical bases remain, the pace of decline may be expected to decelerate.

We believe that the major determinant of the rate of decline in the future will therefore be the level of fertility itself. This results from the very close relationship between the birth rate and the proportion of couples who practice contraception. If the birth rate is high, it is expected that the annual decline will be smaller (despite the level of the family planning effort) because under these circumstances only a small fraction of the population are contraceptors, the behavior is less socially accepted, and those who practice must do so as "pioneers". As birth rates fall to lower levels, a greater percentage of the public practices contraception. Following is an estimate of the proportion of fertile couples of reproductive age who must be practicing contraception in order for the birth rate to be at each of the levels specified:

Crude birth rate	Percent of fertile couples contracepted
60	0.0
55	8.4
50	16.7
45	26.5
40	33.3
35	41.7
30	50.0
25	58.3
20	66.7
15	75.0
10	80.5
5	91.7
0	100.0

Source: Computed from equation 20a, of RFFPI Manual 6, An Empirical Model for Demographic Evaluation of the Impact of Contraception and Marital Status on Birth Rates, Community and Family Study Center, 1973. p.32.

Thus, when the crude birth rate is 60, there is zero contraception. With each lower level of fertility, the prevalance of contraception increases, so that by the level of CBR=45, roughly one-fourth of the fertile women are protected by some form of contraception. This can be via delayed marriage, abstinence, withdrawal, induced abortion, rhythm, or some other "folk" method. When CBR=30, one-half of the women are contracepting, and family planning passes from being a minority to a majority trait. When CBR=15 (roughly replacement level fertility), three-fourths of all fertile women are contracepting. It is this passage from deviational behavior to majority status that causes the pace of fertility decline to increase with declining fertility. (The proportions reported above assume perfect contraception. Taking into account accidental pregnancies resulting from use of unreliable methods and carelessnes, the percentage of couples who must actually practice some form of contraception or fertility regulation in order to achieve this amount of perfect contraception is somewhat greater than the proportions indicated.)

Studying the above percentages of contraceptive prevalence related to fertility levels, we note that at CBR=40 approximately one-third of the couples are practicing contraception. This is the point at which, in most adoption research, "early adoption" gives way to "mass adoption". At about this point, therefore, we should look for swift fertility declines. This has proven to be the recent experience in many parts of the world; once the birth rate sinks into the high thirties it tends to descend swiftly into the mid-twenties. We predict it will be come a universal phenomenon in the remainder of this century and the beginning of the next.

As the replacement level is approached, roughly three-fourths of couples are contracepting. Only the most conservative and firmly pronatalist segments remain, along with young couples just starting their families. The pressures to reduce fertility have begun to diminish. Consequently, the pace of fertility decline may be expected to decrease.

If the population has exceeded its resources, and there is genuine and severe overpopulation, we may expect birth rates to decline below the replacement level and to remain there for a sustained period of time, until population growth has not only been brought to zero, but until absolute population decline has reduced the population size to an amount more consistent with life-sustaining resources.

We hypothesize that due to the rapid pace of modernization, religious public and political resistance to family planning, and inadequate communication to give the public advance warning, most of the developing countries will be severely overpopulated by the time they begin to approach the replacement level of fertility (CBR=15). It is our prediction, therefore, that they will proceed immediately and directly to substantial and sustained below-replacement fertility. They may remain in this state for a full quarter or half century until their numbers and resources are in balance so that they can enjoy an improved standard of living. We predict that much of the twenty-first century will be one of replacement level or below-replacement level fertility throughout the world, including most, if not all, of the present high birth rate countries of Asia, Latin America, and Africa.

V

Predicted Fertility Trends: 1975 to 2075

Based on the assumptions stated above, it is possible to chart out new paths for future trends that offer the possiblity of being more realistic and more likely to occur than those used in the past. Actually, there are three basic assumptions:

(a) The rate of fertility decline will be directly proportional to the amount of family planning effort (on a per capita basis) and the quality of those efforts.

(b) The rate of fertility decline will be a function, "inverse S curve," of the birth rate itself.

(c) Steady but not necessarily spectacular progress will be made in other aspects of economic and social development. This calls for continuation, at about present rates, in efforts to reduce infant mortality, promote adult literacy, raise the standard of living, and promote community development. Progress on all of the fronts has been underway to some degree in most countries for almost a quarter-century (since 1940), and in major proportions for a decade. Without continued progress along these fronts, the assumptions stated above will not operate as predicted. We assume, in other words, that rapid fertility decline is not in either economic development or family planning programs, but the simultaneous conduct of both.

Implicit in this are the following corollaries:

(a) The rate of decline will be roughly the same in all continents, cultures, religious groups, or levels of economy. Well-planned and skillfully executed national family planning programs (both in the public information/motivation front and in the provision of convenient, inexpensive, and high quality contraceptive service) are progressively capable of overcoming the barriers to success that created earlier differentials along these cultural and economic lines. This will be especially true under conditions of economic progress.

(b) The major determinant in determining the future course of a nation is the date at which it sponsors a nationwide family planning program of adequate dimension and how sincerely and skillfully that program is carried out.

If these assumptions and corollaries are accepted as premises for making population projections, the question then arises: What rates of fertility decline can realistically be expected under conditions of organized family planning programs? Based on a study of recent trends in countries where fertility declines have taken place in the presence of major family planning programs, we have prepared schedules of predicted annual decline (expressed in units of crude birth rate). We assume three possible levels of predicted annual decline expected under each of these conditions.

Table 2 shows the number of years that would be required for a population to pass through each range of birth rates, under the three assumptions. For example, in a strong family planning program, it is estimated that the birth rate would decline from 45 to 40 within 4 years, because the birth rate is expected to decline 1.25 points per year. A medium strength program would require 6.7 years; a weak program would require 15 years.

At the foot of Table 2 is a summary reporting the number of years that would be required to pass through the demographic transition from a CBR=45 to replacement level fertility of CBR=15. Under a strong family planning program, under modern conditions, only 18.5 years would be required. Under a moderately strong program, a little more than a quarter century would be required (26 years). Under a weak program, more than two-thirds of a century (68 years) would be required.

VI

Empirical Support for the Predicted Fertility Declines

Empirical support for the predicted amount of fertility decline to be expected during the next century, under alternative conditions of strength of family planning effort, are provided from a careful scrutiny of recent fertility declines in developing and developed countries. We have worked on the assumption that most family planning programs were poorly organized, not well planned, and clumsily executed before 1968, and that only fertility trends since that date should be considered as typical of the potential that can be expected in future years.

We have made estimates of the rate of Total Fertility (TFR) as of 1968, interpolating where necessary between adjacent measures. We have made a similar estimate for 1975, extrapolating the most recent annual decline where necessary to arrive at a consistent date. Where there is no change in fertility, rates for 1968 and 1975 are, of course identical. (Because we believe the rate of fertility decline to be in the acceleration phase in most developing countries, the above procedure tends to understate the true amount of fertility decline, rather than exaggerate it.)

A careful analysis of the changes in fertility, 1968 to 1975, has been made, taking into account the level of family planning effort, the continent on which the nation is located, and other factors. The results of this analysis strongly support the inference that the schedule of fertility declines prescribed for the "moderate" family planning effort could readily take place in any country on earth, given a willingness of the national government to sponsor it. Empirical support that the more rapid declines prescribed for a "strong" family planning program could be achieved in most countries of Asia and Latin America is also ample. Our schedule for the "weak" family planning program is more or less an intuitive synthesis of our empirical results for "no family planning program" and current weak family planning program efforts. Following is a more detailed description of the analysis and of the findings.

(To Be Completed)

Editor's note: The CFSC intended originally to edit and expand this paper, but instead wrote a substantially different paper, which follows.

Table 1

PREDICTED ANNUAL DECLINE IN CRUDE BIRTH RATE, UNDER THREE ASSUMPTIONS OF THE STRENGTH OF THE FAMILY PLANNING EFFORT

	Strength of Family Planning Effort		
Crude Birth Rate	Strong	Moderate	Weak
45 and over	1.00	.50	.25
40-44	1.25	.75	.33
35-39	1.50	1.00	.50
30-34	1.75	1.25	.75
25-29	2.00	1.50	1.00
20-24	2.00	1.50	.75
15-19	1.50	1.25	.50
10-14	1.25	.75	.33

Table 2

NUMBER OF YEARS REQUIRED TO PASS THROUGH THE CRUDE BIRTH RATE INTERVAL

	Strength of Family Planning Effort		
Crude Birth Rate	Strong	Moderate	Weak
45 and over	---	---	---
40-44	4.0	6.7	15.0
35-39	3.3	5.0	10.0
30-34	2.9	4.0	6.7
25-29	2.5	3.3	5.0
20-24	2.5	3.3	6.7
15-19	3.3	4.0	10.0
10-14	4.0	6.7	15.0
Time required to decline from CBR=45 to CBR=15	18.5	26.3	68.4

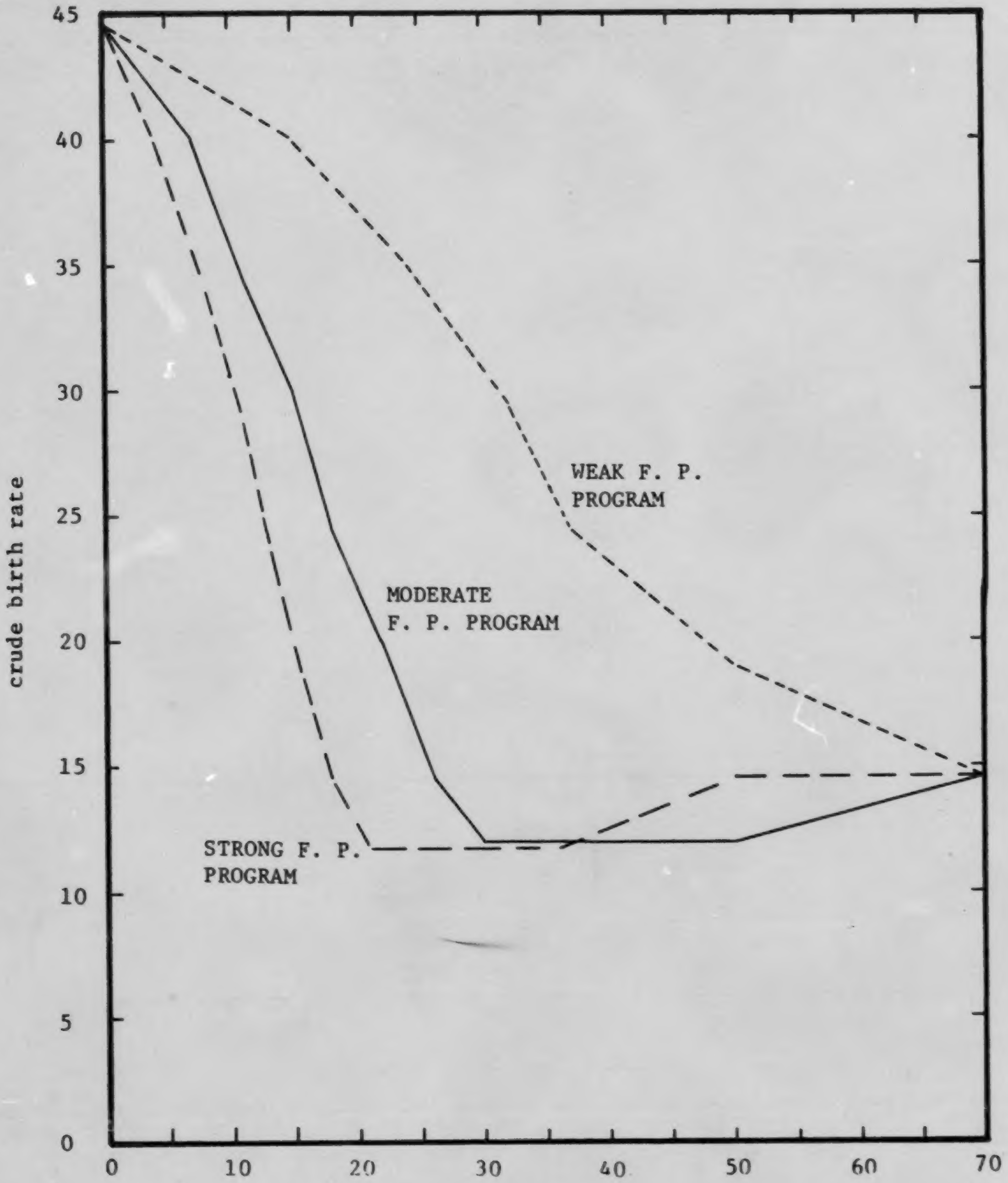
45
40
35
30
25
20
15
10
5
0
crude birth rate
0
10
20
30
40
50
60
70
years after initiation of family planning program
WEAK F. P.
PROGRAM
MODERATE
F. P. PROGRAM
STRONG F. P.
PROGRAM

FIGURE ONE

POPULATION PROJECTIONS FOR THE WORLD: 1975-2000

Individual Countries and Regions

Prepared by

Amy Ong Tsui and Donald J. Bogue

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Editor's note: This paper was submitted by the Community and Family Study Center (CFSC) to the Global 2000 staff in response to a request for further information on the methods and assumptions used by CFSC in developing projections for the Global 2000 Study.

October, 1977

Acknowledgements

The demographic work reported here is based upon data and analysis conducted by others who generously have made them available to us. Without these basic data, the projections reported here could not have been made. Computation of future populations relies upon a reliable estimate of the population as of the base (starting) date for the projections and of fertility and mortality rates as of that date. Much meticulous and painstaking research is required to arrive at these basic data, especially for the less developed nations which lack good census and vital registration facilities. It is imperative, therefore, to acknowledge the persons and organizations upon whose sustained and careful work the present projections are based.

Dr. K.C. Zachariah of the World Bank and staff supplied most of the basic data used in these projections. Dr. Zachariah has reviewed the census and other population information for each nation of the earth to arrive at the best possible estimate of its population, by age and sex, for the year 1975, and has estimated fertility and mortality rates for that year. His data, adjusted slightly for individual countries in the light of other information, are the foundation upon which the present projections are built.

Dr. S. Kono, Director of Population Projections in the Population Division of the United Nations, also provided all of the basic population counts, birth rates, and death rates used by the United Nations in making its population projections. Inasmuch as Dr. Zachariah and Dr. Kono had already cooperated to review these data, country by country, we were exploiting fully the meticulous work of the United Nations, updated to 1975 by using the World Bank estimates.

Mr. Chao, Demographer of the Evaluation Division, Office of Population, U.S. Agency for International Development, maintains a data bank of information on population counts, birth rates, and death rates for all nations of the earth. His archives contain information compiled by demographers in the respective countries, work by academic and other nongovernmental research centers, and data compiled for official use by planning commissions and other agencies within the country. All of this information was made available for comparison with the data from the World Bank and the United Nations.

Dr. James Palmore of the Demographic Institute, East-West Center, has completed a new set of estimates of the fertility of each nation of the world, using a multiple-regression approach on census data for countries where registration is deficient. His estimates were available for comparison with other data.

The assumptions used in making the present projections were reviewed by a panel of experts. A one-day conference on the assumptions was held in Chicago on September 28, 1977. Present were:

James Palmore
Deputy Director, Population Institute, East-West Center

W. Parker Mauldin
Population Council

Tomas Frejka
Demography Division, Population Council

Martin Frankel
National Center for Education Statistics, Department of HEW

Teresa Sullivan
Assistant Professor, University of Chicago

John Chao
Office of Population, Agency for International Development

Lawrence Kegan
Director, Population Crisis Committee

Gerald Barney
Council on Environmental Quality

Samuel Baum
International Statistical Program Center, Bureau of the Census

Robert J. Lapham
Study Center for Committee on Population and Demography, National Academy of Sciences

K.C. Zachariah
World Bank

Shigemi Kono
Chief, Estimates and Projections Section, Population Division, United Nations

The opinions and advice of this panel strongly influenced the final assumptions about the future course of births and deaths adopted in making the projections.

Given this complete access to the most reliable sources of basic data available, our contribution appears to be a comparatively minor one. We have merely imposed upon these data a particular set of assumptions about the future course of fertility, based upon our own research. The colleagues listed above do not necessarily agree with these assumptions. While excusing them from agreement with our projection results, we gratefully acknowledge that we have done little more than manipulate their data with our perspective about future birth trends.

POPULATION PROJECTIONS FOR THE WORLD: INDIVIDUAL COUNTRIES AND REGIONS, 1975-2000

Amy Ong Tsui and Donald J. Bogue

Community and Family Study Center

University of Chicago

In order to provide a basis for planning and predicting future needs for food, energy, employment, community facilities, and social services, a set of population projections has been prepared which reflects the most recent data in world fertility and mortality. Three estimates have been submitted, with the objective that they will be very likely to "bracket" actual future trends:

"High" projection	The highest population counts that reasonably could be expected in future years, given present trends and knowledge of underlying factors that are affecting those trends;
"Medium" projection	The "best guess" or "most likely" population counts that could be expected in future years, given present trends and knowledge of underlying factors;
"Low" projection	The lowest population counts that reasonably could be expected in future years, given present trends and knowledge of underlying factors that affect them.

It is expected that the actual course of future population growth will follow a path close to that specified by the "medium" projection. If actual trends deviate from this, they are not expected to be higher than the "high" projections nor lower than the "low" projections.

These projections have been prepared for each of the twenty-six years, 1975 to 2000. Each projection reports the total population that may be expected, by age and sex. Age is specified in terms of five-year groupings.

After review and discussion by a panel of experts in population projection, it is planned to translate these projections into "functional" projections for school enrollment, employment, food, community facilities, housing, etc.

The projections are made for every nation of the earth recognized by the United Nations. For the purposes of providing data to the Committee on Environmental Quality of the United States, certain of these countries have been summed into regional groupings.

Methodology. The projections have been prepared using a procedure known as the "component method" of population projection. Under this procedure, a set of assumptions about the future trend in the three components which determine population growth--fertility, mortality, and migration--are scheduled to show exactly what impact they would have on population counts. This procedure is very well known and widely accepted by demographers as the most explicit and best procedure for making population projections. It was developed by Warren S. Thompson and P.K. Whelpton of the Scripps Foundation in the early 1930s, and has become the standard procedure for forecasting population throughout the world. The details of the procedure, together with a computer program POPROJ which carries out the scheduling of anticipated changes in fertility, mortality, and migration, are reported in a publication, RFFPI Manual 12.[1]

Given the fact that the methodology employed in making population projections is standardized throughout the world, the difference between one set of population projections and another is determined entirely by the differences between four sets of data:

(a) the population count, by age and sex, for the base (beginning) date for the projections,

(b) the age-specific rates of mortality as of the base date and expected for future years,

(c) the age-specific rates of fertility as of the base date and expected for future years,

(d) the age-specific amounts of new migration expected for future years.

The "specifications" for a set of population projections consist, therefore, in providing details of assumptions about each of the four sets of data. These are provided below for the projections reported here.

Assumptions upon which the Projections are Based

Mortality. Throughout the world there is a slow but nevertheless steady increase in survivorship over mortality. That increase is greatest in developing countries where mortality rates have been high, and least in developed countries which have already pushed public health and medical technology almost to the limits of their life-saving capability. The United Nations has made detailed and careful studies of trends in mortality decline, and has projected future declines in mortality that may be expected, assuming that national and international efforts to provide health and medical care to the population continue. These projected declines have been carefully reviewed by the World Bank. It has been observed that in recent years the declines in mortality have not been as great as those anticipated by the United Nations in certain countries, especially those classified as "underdeveloped." The World Bank, therefore, has rescheduled the expected future mortality (survivorship) rates on a somewhat less optimistic basis. In most cases, these revisions have been reviewed with the United Nations, and it is expected that future United Nations assumptions will also reflect the slower progress in mortality reduction encountered in recent years.

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[1] Donald J. Bogue and Louise Rehling, Techniques for Making Population Projections: How to Make Age-Sex Projections by Electronic Computer, Family Planning Research and Evaluation Manual Number 12, Chicago: University of Chicago/Community and Family Study Center, 1974.

For the projections prepared by the Community and Family Study Center, the mortality assumptions of the World Bank have been accepted without change. This has been done for two reasons:

1. The Community and Family Study Center has no research or data to cast any doubt upon the validity of the World Bank's review, and believes the World Bank's assessment of mortality trends to be essentially correct.

2. The impact upon projected future population counts of the mortality component is much smaller than that of fertility. A revision of the World Bank's assumptions about mortality could have only a comparatively minor effect upon the population projections.

Both the United Nations and the World Bank express mortality in terms of survivorship ratios based upon model life tables prepared by Ansley Coale and Paul Demeny of Princeton's Office of Population Research. There are three such sets of model life tables, North, South, and West. Each of these sets specifies a rate of survivorship for a one-year period for various levels of mortality, expressed in average expectation of life at birth (e^0). Thus, assumptions about future trends in mortality are expressed in terms of the future expectation of life at birth, and the age-specific survivorship values specified by one of the model life tables for that particular expectation-of-life level. We have accepted this procedure without modification. Thus, our assumptions about the future course of mortality and our method of converting this into the computation of population projections are identical to that proposed by the World Bank, after reviewing the United Nations mortality projections in the light of recent data.

Migration. For the projections reported here, we assume zero net migration. This assumption is approximately valid for most nations of the world, but clearly is invalid for several--of which the United States is the most conspicuous. A separate projection for the U.S., in which realistic assumptions about future migration are incorporated, is submitted for special consideration. At a future date, projections for other countries which experience significant amounts of in-migration or out-migration will be prepared. The assumption of zero net migration, for the current series of projections, is used more because of a lack of valid data (and a lack of a basis for making assumptions about the future trend of migration) than because of a belief that this component will actually remain zero.

Fertility. At the national level, fertility has considerably more potential for change and hence is more important than the other two components of population growth. Consequently, the assumptions made about current levels and future trends in the birth rate reflect the major determinant of future population growth. The "validity" of population projections depends, therefore, primarily upon the assumptions made concerning fertility.

The fertility assumptions made for the present projections rest upon a theoretical base somewhat different from that employed in previous sets of population projections. The detailed argument upon which it is based is reported in an article, "Fertility

Trends Over the Next One Hundred Years."[2] The basic premises of this argument are as follows:

1. Throughout the entire world, in developed and developing societies, the need to reduce the pace of population growth is being increasingly felt. This pressure is being manifested both at the aggregate (governmental and policy) level and at the level of the family and the individual person. Modernization is inherently inconsistent with high fertility, and high fertility is inherently inconsistent with most of the objectives and life-goals being sought by most peoples (literacy, health, higher standard of living, better housing, basic luxury commodities, physical comfort). Even in nations where this set of pressures has not been officially recognized, they are present and mounting in the individual families. Environmental, economic, and social pressures will maintain this pressure, and increase it substantially during the remainder of this century.

2. The present pace of economic development and modernization will bring down fertility to the replacement level gradually through provision of facilities and gradual accumulation of knowledge and motivation. The pace will be somewhat faster than that followed by the West (Europe and North America) during the nineteenth and early twentieth centuries because of improved communication and improved methods of contraception.

3. The pace of fertility decline is directly influenced by family planning programs, organized on a national or regional basis to provide information, motivation, and contraceptive services for family planning. The greater the percapita investment, the more wholehearted the official support, and the higher the accessibility to the entire public of these services, the more rapid will be the decline.

4. The pace of decline of fertility will be that of a "reverse S" curve. When birth rates are high, and family planning programs are in their stages of establishment and gaining social acceptance, the pace will be slow. As birth rates sink to lower levels, the rate of decline will accelerate to a maximum point, when the Crude Birth Rate is between 38 and 20. In this interval, the pace may be very rapid. When the Crude Birth Rate reaches the lower 20s, complete saturation of contraception is being approached. Only young people still starting their families and a residue of reactionary "late adopters" will remain to be convinced about the need for fertility decline. At this point, fertility decline continues, but at a decelerating rate.

5. Those countries which now have no family planning programs may be expected to begin at least weak (partial) programs within the very near future. Nations which presently have weak or moderate family planning programs may be expected to strengthen them substantially. By the end of the century, every nation on earth may be expected to have at least some kind of a substantial family planning effort (either public or private or both) and these programs may be expected to have a substantial impact in

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[2] Donald J. Bogue and Amy Ong Tsui, "Fertility Trends Over the Next One Hundred Years," unpublished manuscript, to be submitted to a professional journal.

reducing fertility faster than otherwise would be the case.

Table 1 represents an effort to operationalize the above five points. The right hand column specifies the estimated annual decline in the Crude Birth Rate that may be expected in the future on the basis of modernization alone, with no special efforts at providing family planning information and services. The anticipated downward trend is almost linear, with a one-point decline in the Crude Birth Rate every 4 or 5 years. Under this set of conditions, it would require about 135 years for a population to make the demographic transition from a Crude Birth Rate of 45 to the replacement level of about 15 per thousand.

The extreme left column of Table 1 specifies the annual decline in the Crude Birth Rate that may be expected in the presence of a strong, well-financed, well-organized, and well-administered family planning program that reaches the entire population, both urban and rural, in a sustained way. Under these conditions, it is estimated that the annual rates of decline are two to four times those that would occur in the absence of a program. This acceleration in the pace of decline is estimated to be able to bring about a complete demographic transition from a Crude Birth Rate of 45 to a CBR of 15 within a span of about 38 years, or about one-fourth the time that would be required in the absence of a family planning program.

The assumptions of Table 1 were converted to predicted annual declines for individual countries and regions of the world by using the following assumptions:

1. Each country is classified into one of four categories, according to the level of its family planning program effort: "Strong," "Moderate," "Weak," or "None."

2. The high estimate assumes that each country will maintain its present family planning status, and will follow out the schedule of changes indicated for that status by Table 1. This yields a set of anticipated annual changes in the Total Fertility Rate that would be expected under this set of assumptions. (Table 2 is expressed in terms of Total Fertility Rate instead of Crude Birth Rate because that is the unit of measure usually employed in the population projection procedure. It escapes several methodological difficulties pertaining to age composition, sex ratios, and interaction between fertility and mortality.) Each cell of Table 2 reports the number of fewer children 1000 women would bear each year, under conditions of strong, moderate, weak, or no family planning program, according to the level of the birth rate in that year. (The level of fertility is expressed both in terms of Crude Birth Rate and Total Fertility Rate, for convenience in interpretation.)

3. The medium projections (deemed most likely to take place) assumes that the schedule of fertility declines shown in Table 1 will occur, but that in addition, the respective nations will strengthen their family planning programs as follows:

   (a) Nations which presently have no family planning program will remain in that status for five years (until 1980), and then linearly trend toward a weak program by 1985. They will then trend toward a "moderate" family planning program by 1990 and a "strong" family planning program by the year 2000.

   (b) Nations which presently have a moderate family planning program will remain in that status for five years, and then will trend toward a strong family planning program by 1990 and reamin in that status until the year 2000.

(c) Nations which presently have "strong" family planning programs will remain in that status for the entire span of time.

Table 3 schedules out the annual decline in the Total Fertility Rate expected under these conditions. Each cell of these tables has the same meaning as that stated for Table 2. However, the table is more complex (has more panels) because a separate schedule must be made according to the present level of the national family planning effort, and a schedule must be made for each five-year period, 1975-2000.

4. The low projections (deemed less likely but nevertheless possible) assumes a much greater family planning effort than for the medium projections. It assumes that the respective nations will strengthen their family planning programs as follows:

(a) Nations which presently have no family planning programs will linearly trend toward a "weak" program by 1985, a "moderate" program by 1990, and a strong program by the year 2000.

(b) Nations which presently have a "moderate" family planning program will trend linearly toward a "strong" family planning program by 1980 and will remain in that status until 2000.

(c) Nations which presently have a "strong" family planning program will remain in that status for the entire span of time, but the efficacy of the program will improve linearly from its present thrty-eight years for transition time to one-half that amount (to nineteen years), equivalent to doubling the coefficients in Table 1 for the "strong" program.

Mininimum allowable fertility levels. When carried out mechanically, some of these assumptions (especially the "low" projections) will call for birth rates that are absurdly low. It is assumed that when birth rates approach the replacement levels (CBR = 14 or TFR = 2.1), there will be allowed no stronger resistance to further fertility decline. The birth rates will be allowed to sink to a minimum level and it is assumed that they will remain at this level for the remainder of the century. These minimum levels are as follows:

For high projections, TFR = 2000 (CBR of about 14)

For medium projections, TFR = 1900 (CBR of about 13.5)

For low projections, TFR = 1800 (CBR of about 13).

Thus, the medium and low projections permit fertility to sink somewhat below replacement levels and remain there indefinitely.

Nations which are currently below replacement levels. The nations of Western Europe and North America are already below replacement. It is anticipated that they will remain in this state for a period of ten years and will then trend linearly toward replacement by the year 2000; for medium and low projections, the rates trend linearly toward 1900 and 1800 respectively. As these countries reach a stage of absolute zero growth, it is expected that systems of subsidies and other inducements will be launched which will seek to encourage fertility.

Conclusion

These projections, and the basic theory which underlies them, are fully consistent with the most recent data concerning birth declines. However, it must be emphasized that these projections are based upon the assumption that there will be a continuing well-financed and well-sponsored program of international assistance to developing countries over the next quarter century. It is expected that these programs will expand to cover all nations, and will improve within each nation. If that is carried out, it is believed that the projections will follow the course specified by our "medium" projections, or even deviate downward towards the "low" projections. If it is neglected, weakened, or rendered ineffective by too much dilution with other programs, the course of birth trends will veer sharply upward towards the "high" projections, and if the program is discontinued or substantially weakened, it can exceed the "high" projections.

Table 1

ESTIMATED ANNUAL DECLINES IN CRUDE BIRTH RATE AND TOTAL FERTILITY RATE FOR VARIOUS STRENGTHS OF FAMILY PLANNING EFFORT

	STRENGTH OF FAMILY PLANNING EFFORT			
CRUDE BIRTH RATE	Strong	Moderate	Weak	None
	Annual Declines in Crude Birth Rate			
45 and over	.40	.333	.25	.20
40-44	.60	.50	.30	.20
35-39	.80	.667	.40	.25
30-34	1.00	.75	.50	.25
25-29	1.00	.667	.40	.25
20-24	.80	.50	.30	.20
15-19	.60	.333	.25	.20
13-14	.40	.25	.15	.15
	Annual Declines in Total Fertility Rate			
40-44	8.0	10.0	17.0	.25
35-39	6.0	8.0	12.0	.25
30-34	5.0	7.0	10.0	.20
25-29	5.0	8.0	12.0	.20
20-24	6.0	10.0	17.0	.25
15-19	8.0	15.0	20.0	.25
Time required to decline from CBR=45 to CBR=15	38.0	58.0	88.0	1.35

Table 2. High Estimate

ESTIMATED ANNUAL DECLINES IN TOTAL FERTILITY RATE BY LEVEL OF FERTILITY AND STRENGTH OF FAMILY PLANNING PROGRAM

Fertility level		STRENGTH OF FAMILY PLANNING PROGRAM			
TFR	CBR	Strong	Moderate	Weak	None
6245 and over	45	55.18	45.52	34.49	27.59
5556-6244	40-44	82.76	68.97	41.38	27.59
4866-5555	35-39	110.35	92.42	55.18	34.49
4176-4865	30-34	137.94	103.46	68.97	34.49
3487-4175	25-29	137.94	92.42	55.18	34.49
2797-3486	20-24	110.35	68.97	41.38	27.59
2107-2796	15-19	82.76	45.52	34.49	27.59
1899-2106	13-14	55.18	34.49	20.69	20.69

Table 3. Medium Estimates

ASSUMED ANNUAL DECLINES IN TOTAL FERTILITY RATE BY LEVEL OF FERTILITY AND STRENGTH OF FAMILY PLANNING PROGRAM, UNDER PATTERN OF IMPROVING FAMILY PLANNING PROGRAMS ASSUMED FOR MEDIUM (MOST LIKELY) PROJECTIONS

A. STRONG FAMILY PLANNING PROGRAM IN 1975

Fertility level TFR	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
6245 and over	55.18	55.18	55.18	55.18	55.18
5556-6244	82.76	82.76	82.76	82.76	82.76
4866-5555	110.35	110.35	110.35	110.35	110.35
4176-4865	137.94	137.94	137.94	137.94	137.94
3487-4175	137.94	137.94	137.94	137.94	137.94
2797-3486	110.35	110.35	110.35	110.35	110.35
2107-2796	82.76	82.76	82.76	82.76	82.76
1899-2106	55.18	55.18	55.18	55.18	55.18

B. MODERATE FAMILY PLANNING PROGRAM IN 1975

Fertility level TFR	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
6245 and over	45.52	48.28	51.04	55.18	55.18
5556-6244	68.97	73.11	77.25	82.76	82.76
4866-5555	92.42	97.94	103.46	110.35	110.35
4176-4865	103.46	114.49	125.53	137.94	137.94
3487-4175	92.42	107.59	122.77	137.94	137.94
2797-3486	68.97	82.76	96.56	110.35	110.35
2107-2796	45.52	57.93	70.35	82.76	82.76
1899-2106	34.49	41.38	48.28	55.18	55.18

C. WEAK FAMILY PLANNING PROGRAM IN 1975

Fertility level TFR	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
6245 and over	34.49	38.62	42.76	45.52	51.04
5556-6244	41.38	49.66	59.31	68.97	75.87
4866-5555	55.18	67.59	80.00	92.42	100.70
4176-4865	68.97	80.00	91.04	103.46	120.00
3487-4175	55.18	67.59	80.00	92.42	114.49
2797-3486	41.38	49.66	59.31	68.97	89.66
2107-2796	34.49	38.62	42.76	45.52	64.83
1899-2106	20.69	24.83	28.97	34.49	44.14

Table 4. Low Estimates

ASSUMED ANNUAL DECLINES IN TOTAL FERTILITY RATE BY LEVEL OF FERTILITY AND STRENGTH OF FAMILY PLANNING RPOGRAM, UNDER PATTERN OF IMPROVING FAMILY PLANNING PROGRAMS ASSUMED FOR LOW (POSSIBLE BUT ATTAINABLE ONLY UNDER STRONGEST POSSIBLE FAMILY PLANNING EFFORT) PROJECT

A. STRONG FAMILY PLANNING PROGRAM IN 1975

Fertility level TFR	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
6245 and over	55.18	68.97	82.76	96.56	110.36
5556-6244	82.76	103.46	124.15	144.84	165.53
4866-5555	110.35	137.94	165.53	193.12	220.70
4176-4865	131.94	172.43	206.91	241.40	275.88
3487-4175	137.94	172.43	206.91	241.40	275.88
2797-3486	110.35	137.94	165.53	193.12	220.70
2107-2796	82.76	103.46	124.15	144.84	165.53
1899-2106	55.18	68.97	82.76	96.56	110.36

B. MODERATE FAMILY PLANNING PROGRAM IN 1975

Fertility level TFR	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
6245 and over	45.52	55.18	67.59	80.00	92.42
5556-6244	68.97	82.76	100.70	118.63	137.94
4866-5555	92.42	110.35	135.18	160.00	184.84
4176-4865	103.46	137.94	161.39	184.84	206.91
3847-4175	92.42	137.94	153.11	168.29	184.84
2797-3486	68.97	110.35	120.00	129.66	137.94
2107-2796	45.52	82.76	85.52	88.28	92.42
1899-2106	34.49	55.18	59.31	64.83	68.97

C. WEAK FAMILY PLANNING PROGRAM IN 1975

Fertility level TFR	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
6245 and over	34.49	40.00	45.52	9.66	55.18
5556-6244	41.38	55.18	68.97	75.87	82.76
4866-5555	55.18	73.11	92.42	100.70	110.35
4176-4865	68.97	86.90	103.46	120.00	137.94
3487-4175	55.18	73.11	92.42	114.49	137.94
2797-3486	41.38	55.18	68.97	89.66	110.35
2107-2796	34.49	40.00	45.52	63.45	82.76
1899-2016	20.69	27.59	34.49	44.14	55.18

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October 31, 1977

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Editor's note: This letter and its enclosures were prepared by the CFSC staff and sent to Dr. Baum at the Bureau of the Census. A copy was also sent to the Global 2000 central staff.

Dr. Samuel Baum
International Statistical Programs Center
Bureau of the Census
Department of Commerce
Washington, D.C. 20233

Dear Dr. Baum:

Enclosed please find a set of summary tables for the Community and Family Study Center's population projections for those areas requested by the Council on Environmental Quality. I am sorry for the delay in getting these to you and your staff since the October 13th meeting.

The last two weeks have kept me occupied comparing among the Census Bureau's, the United Nations', the World Bank's and our projection results. While some large differences are inevitable, it is heartening that no duplication of effort occurs. I understand that the World Bank has provided you with their figures and perhaps your independent comparison will shed further light on our findings:

1. Base Population Data - (See Table I in folder) Our 1975 data, i.e., the World Bank's, tend to differ on the low end from your high, medium and low estimates by only 1.9, 1.3 and 0.9 percent respectively. The major differences are located in the estimates for China and South Korea. Your low estimates and our base figures appear to correspond fairly well.

2. Fertility Rates - (See Table II in folder) This is perhaps the area for greatest discrepancy. We have adopted the World Bank/United Nations' total fertility rates for 1975 except for China, Indonesia, Pakistan, Philippines, Thailand, South Korea and the U.S.A.. The Asian countries, we believe, are undergoing a fertility decline not adequately reflected in the TFRs used by the two international agencies. Our figures have been taken from estimates by the East-West Population Institute and U.S.A.I.D.. For this group of Asian nations, the starting TFRs differ from your high, medium and low estimates by -14.8, -7.7 and 1.3 percent respectively. (The differences can largely be attributed to estimates for China's 1975 fertility.)

3. Projections to the Year 2000 - (See Tables A and B attached) Because of the differences above, additional minor deviations in mortality assumptions and the assumed degree of fertility decline, our projections produce considerably different results. Although we consider our medium estimates to be our "best estimates", we have drawn most of our comparisons using our high estimates.

letter to Samuel Baum
October 31, 1977
Page 2

Our optimism shows through with the CFSC high projection for the world being lower than your low projection. However, on a country-by-country basis, our high is on the average 1 percent greater than the Bureau's low, 3 percent lower than the World Bank's only variant, and 2.6 percent lower than the U.N.'s low. These percentage differences taken our different starting base populations into account. The amount of difference over the 25-year period is not substantial.

We are considering some modifications to our fertility decline schedules but probably the overall change will be minimal. In addition, we caution that the total projections for the world and regions are still subject to revision. We expect the spread between the high and low estimates to increase as we refine our individual country estimates. I would be interested in hearing of any comparisons you are making or of any significant discrepancies you may uncover in our data. The projections have been an extremely stimulating and educational exercise but carry their weight in policy implications.

We would be happy to consider changes in our parameters in light of new evidence not available to us. I am also looking forward to visiting your Center sometime in late November. With best regards,

Sincerely yours,

Amy

Amy Ong Tsui
Assistant Director

Enclosure

cc: Richard Cornelius
Gerald Barney

Table I. Total 1975 Population Estimates for World, Major Regions, and Selected Countries, As Estimated by CFSC and Census Bureau, and Percentage Difference[1]

		CENSUS BUREAU			% OF DIFFERENCE WITH B.C.		
	CFSC	High	Medium	Low	High	Medium	Low
World	4,020,707	4,134,049	4,090,133	4,043,444	-2.8	-1.7	-0.6
Major Regions							
Africa	402,940	398,694	398,694	398,694	1.1	1.1	1.1
Asia and Oceania[2]	2,208,215	2,318,028	2,274,471	2,228,443	-5.0	-3.0	-0.9
Latin America	312,291	325,085	324,725	324,064	-4.0	-4.0	-3.8
U.S.S.R. & E. Europe[3]	384,407	384,336	384,336	384,336	0.0	0.0	0.0
OECD[4]	743,686	707,906	707,906	707,906	-4.8	-4.8	-4.8
Nations							
People's Rep.China	896,806	977,862	934,626	889,015	-9.0	-4.2	0.9
India	607,374	618,470	618,471	618,471	-1.8	-1.8	-1.8
Indonesia	130,496	134,988	134,988	134,988	-3.4	-3.4	-3.4
Bangladesh	79,314	79,411	79,411	79,411	-0.1	-0.1	-0.1
Pakistan	70,267	70,974	70,974	70,974	-1.0	-1.0	-1.0
Philippines	41,817	43,029	42,810	42,630	-2.9	-2.4	-1.9
Thailand	41,648	42,473	42,420	42,352	-2.0	-1.9	-1.7
S. Korea	35,274	36,895	36,846	36,677	-4.6	-4.5	-4.0
Egypt	37,766	36,859	36,859	36,859	2.4	2.4	2.4
Nigeria	62,921	62,925	62,925	62,925	-0.0	-0.0	-0.0
Brazil	106,997	108,882	108,797	108,524	-1.8	-1.7	-1.4
Mexico	59,924	60,188	59,913	59,526	-4.4	0.0	0.7
United States	216,625	213,540	213,540	213,540	1.4	1.4	1.4
U.S.S.R.	254,394	254,393	254,393	254,393	0.0	0.0	0.0
Japan	110,955	111,566	111,566	111,566	-0.6	-0.6	-0.6
Eastern Europe[3]	130,012	129,943	129,943	129,943	0.1	0.1	0.1
Western Europe	343,768	343,517	343,517	343,517	0.1	0.1	0.1
Average					-1.9	-1.3	-0.9

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1. Percentage difference based on CFSC estimates.
2. Excludes Japan, Australia, and New Zealand.
3. Includes Albania and Yugoslavia.
4. Northern America, Western Europe, Japan, New Zealand, and Australia.

Table II. Estimated Total Fertility Rate for World, Major Regions, and Selected Countries for 1975 and 2000 by CFSC, World Bank, United Nations, and Census Bureau

	CFSC				UNITED NATIONS			CENSUS BUREAU		
	High	Med.	Low	WORLD BANK	High	Med.	Low	High	Med.	Low
World (1975)	3777	3777	3777		4393	4223	4000	4530	4265	3994
(2000)	2241	1998	1800		3759	3289	2860	3919	3310	2755
Regions										
Africa (1975)	5280	5280	5280		6297	6252	6168	6385	6352	6315
(2000)	3763	3535	3246		5745	5195	4229	5642	5016	4044
Asia & Oceania[1]	4201	4201	4201		n.a.	n.a.	n.a.	5350	4887	4417
	2000	1900	1800		n.a.	n.a.	n.a.	3883	3224	2716
Latin America	4422	4422	4422		5250	5032	4795	5399	5268	5103
	2547	2194	1829		4701	3876	3031	4495	3639	2895
U.S.S.R. and Eastern Europe[2]	2485	2485	2485		n.a.	n.a.	n.a.	2369	2369	2370
	2000	1900	1800		n.a.	n.a.	n.a.	2672	2266	1862
OECD[3]	2256	2256	2256		n.a.	n.a.	n.a.	1970	1970	1970
	2000	1900	1800		n.a.	n.a.	n.a.	2533	2175	1856
Nations										
People's Republic of China	3200	3200	3200	3772	3547	3362	2911	5171	4128	3083
	2000	1900	1800	2150	2460	2255	2091	3075	2562	2050
India	5500	5500	5500	5500	5699	5590	5383	5300	5300	5300
	3206	2886	2471	3353	4116	3499	3087	4500	3500	3000
Indonesia	5120	5120	5120	5524	5565	5381	5258	5324	5324	5324
	2333	2333	1899	3379	4244	3379	3133	4000	3500	2500
Bangladesh	6575	6575	6575	6575	7175	7073	6970	7000	7000	7000
	4501	4085	3409	4353	5125	4777	4305	5000	4250	3500
Pakistan	6265	6265	6265	6876	7175	6970	6724	6900	6900	6900
	4170	3583	3053	4322	4920	4510	4096	5000	4250	3500
Philippines	5505	5505	5505	6388	6380	6042	6001	5400	5071	4800
	2526	2526	2037	3162	4330	3712	3090	3800	3200	2500
Thailand	4850	4850	4850	6200	6349	6033	5843	5168	5050	4900
	2036	2036	1800	3302	4391	3731	3444	3900	3100	2400
South Korea	3580	3580	3580	3977	3776	3550	3301	3925	3789	3410
	2000	1900	1800	2047	2809	2465	2112	3100	2500	2128

Table II (continued)

	CFSC				UNITED NATIONS			CENSUS BUREAU		
	High	Med.	Low	WORLD BANK	High	Med.	Low	High	Med.	Low
Egypt	5210	5210	5210	5210	4903	4800	4592	5819	5819	5819
	2986	2596	2182	2857	4120	3604	3007	4600	3600	2600
Nigeria	6699	6699	6699	6699	6706	6699	6699	6700	6700	6700
	5761	4790	4499	6104	6482	6104	5258	6375	5900	5000
Brazil	5150	5150	5150	5150	5120	4890	4585	5780	5726	5550
	2937	2536	2122	3830	4705	3830	2740	5000	4000	3500
Mexico	6133	6133	6133	6133	6465	6280	6135	6701	6360	5912
	3956	3429	2898	4402	5705	4885	4155	4700	4001	3000
United States	1799	1799	1799	2011	2508	1994	1813	1771	1771	1771
	2000	1900	1800	1933	2802	2102	1803	2697	2096	1694
U.S.S.R.	2417	2417	2417	2417	2458	2396	2314	2406	2406	2406
	2029	1900	1803	2335	2560	2335	2109	2661	2258	1854
Japan	2159	2159	2159	2159	2221	2177	2064	1925	1925	1925
	2000	1900	1800	1889	2126	2091	2091	2300	2100	1800
Eastern Europe[2]	2034	2034	2034		2340	2174	2056	2270	2270	2270
	2000	1900	1800		2510	2237	1992	2680	2270	1870
Western Europe	2205	2205	2205		2169	2040	1897	2022	2022	2022
	2000	1900	1800		2237	2106	1807	2420	2207	1959

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1. Percentage difference based on CFSC estimates.
2. Excludes Japan, Australia, and New Zealand.
3. Includes Albania and Yugoslavia.

Sources:

Community and Family Study Center, Population Projections 1975-2000; World Bank, Population Projections, 1975-2000; United Nations, Selected World Demographic Indicators by Countries, 1950-2000. ESA/P/WP.55, 1975; Bureau of the Census, Population Projections for the World, Major Regions and Selected Countries: 1975 to 2000. Oct. 13, 1977.

TABLE A

ADJUSTED DIFFERENCES BETWEEN CFSC POPULATION PROJECTIONS FOR 2000 FOR SELECTED COUNTRIES AND THE UNITED NATIONS, BUREAU OF THE CENSUS AND WORLD BANK'S PROJECTIONS[1]

YEAR 2000

COUNTRY	CFSC PROJECTIONS	U. N. (LOW)	BUREAU OF CENSUS (LOW)	WORLD BANK
People's Republic of China	1,138,447	-20,017	-47,204	-50,082
India	967,732	3,271	11,131	9,409
Indonesia	194,387	-22,222	-8,047	-18,411
Bangladesh	157,978	10,704	7,035	11,597
Pakistan	134,561	-2,008	7,063	-2,616
Philippines	73,348	-6,990	7,981	-1,758
Thailand	67,034	-14,593	-1,217	-8,662
South Korea	48,748	-1,312	-2,863	-3,029
Egypt	61,155	835	883	1,781
Nigeria	126,850	162	-1,899	-2,980
Brazil	191,146	4,868	-19,962	-14,115
Mexico	125,335	707	13,908	-712
U.S.A.	244,861	-9,496	7,046	-6,464
U.S.S.R.	304,005	-934	8,890	15,692
Japan	130,975	-334	2,805	-2,455

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[1] These differences are adjusted for differing 1975 base population figures. The CFSC projections represent the high variant.

Prepared by the Community and Family
Study Center, October 1977

TABLE B

PERCENTAGE DIFFERENCES (ADJUSTED) BETWEEN CFSC POPULATION PROJECTIONS FOR 2000 FOR SELECTED COUNTRIES AND THE UNITED NATIONS, BUREAU OF THE CENSUS AND WORLD BANK'S PROJECTIONS[1]

YEAR 2000

COUNTRY	CFSC PROJECTIONS	U. N. (LOW)	BUREAU OF CENSUS (LOW)	WORLD BANK
People's Republic of China	1,138,447	-1.9%	-4.2%	-4.4%
India	967,732	0.3	1.1	1.0
Indonesia	194,387	-11.0	-4.0	-9.5
Bangladesh	157,978	7.4	4.4	7.3
Pakistan	134,561	-1.5	5.2	-1.9
Philippines	73,348	-9.0	10.7	-2.4
Thailand	67,034	-21.7	-1.8	-12.9
South Korea	48,748	-2.8	-5.6	-6.2
Egypt	61,155	1.4	1.5	2.9
Nigeria	126,850	0.1	-1.5	-2.3
Brazil	191,148	2.5	-10.3	-7.4
Mexico	125,335	0.6	11.2	-0.6
U.S.A.	244,861	-3.9	2.9	-2.6
U.S.S.R.	304,005	-0.3	2.9	-5.2
Japan	130,975	-0.3	2.1	-1.9

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[1] Percentage differences are adjusted for differences in 1975 base population figures. CFSC high projections used for base.

3 The Gross National Product Sector

Introduction

The U.S. Government does not have a world economic model capable of making disaggregated gross national product (GNP) projections for 20 years or more. Consequently, it was necessary to assemble a set of GNP projections from several sources. The various sources and their use in the Global 2000 Study are explained in Chapters 3 and 16 of Volume 2.

Only incomplete documentation could be obtained for the various sources of GNP projections. The best documented GNP source is the SIMLINK (Simulated Trade Linkages) model, used by the World Bank, but even this model's documentation is badly dated. The best available documentation on SIMLINK is excerpted here from the *SIMLINK Model of Trade and Growth for the Developing World*, published in 1975.[1] Several additional versions of SIMLINK have been developed and put to use, but more current documentation is not available.

The SIMLINK model is not normally used to make projections beyond 1985, but in 1976 the World Bank Staff assisted the Workshop on Alternative Energy Strategies (WAES)[2] in developing GNP projections to the year 2000. On the recommendation of the World Bank staff, the Global 2000 Study used the World Bank/ WAES GNP Projections.

Unfortunately, there is very little documentation of the World Bank/WAES GNP projections. What information is available is presented in a few pages of the *Third Technical Report* of the WAES study.[3] The five relevant pages of the WAES report are reprinted here.

References

1. *The SIMLINK Model of Trade and Growth for the Developing World*, World Bank Staff Working Paper No. 220, Washington: World Bank, Oct. 1975, pp. 1-34 and Appendixes I and II. (A published paper by Norman L. Hicks presents much of the same information: "A Model of Trade and Growth for the Developing World," *European Economic Review*, vol. 7, 1976, pp. 239-550.)
2. Carroll L. Wilson, project director, *Energy: Global Prospects 1985-2000*, New York: McGraw-Hill, 1977.
3. *Energy Supply-Demand Integrations to the Year 2000: Global and National Studies*, Carroll L. Wilson, project director, Paul S. Basile, ed., Third Technical Report of the Workshop on Alternative Energy Strategies, Cambridge, Mass.: M.I.T. Press, 1977, pp. 217-221.

Editor's note: The following material is taken from *The SIMLINK Model of Trade and Growth for the Developing World,* World Bank Staff Working Paper No. 220, Washington: World Bank, Oct. 1975, pp. 1–34, and Appendixes I and II.

THE SIMLINK MODEL OF TRADE AND GROWTH FOR THE DEVELOPING WORLD *

I. Introduction and Background

1. The economic events of the past two years have made the linkages between the world's economies even more obvious. International inflation and rapid changes in commodity prices and rates of real growth in the developed world have had both favorable and unfavorable effects on the developing countries. 1/ The Bank's SIMLINK 2/ model has been designed to allow the full range of these effects to be estimated simultaneously, analysing trade linkages and the growth prospects of developing countries under alternative scenarios of growth and inflation in the developed world, petroleum prices and capital flows. The model is not a theoretical breakthrough, but combines existing modeling techniques into a comprehensive system which can provide inputs for policy decisions relatively quickly.

2. In recent years modeling work involving developing countries has largely been along three broad lines: country models, international trade models and commodity models. While each approach can yield useful insights, none can be used alone to make definitive statements about the linkage effects of world events.

1/ In this paper, "developing countries" or "LDCs" refers to all developing countries except for members of OPEC and centrally planned economies (CPEs). "OECD" countries refers to the more industrialized members of the Organization for Economic Cooperation and Development, excluding Greece, Portugal, Spain, Turkey, Iceland and Yugoslavia.

2/ For Simulated Trade Linkages.

* The author wishes to thank Hollis Chenery, Wouter Tims, Jean Waelbroeck and Nicholas Carter for their advice and guidance, and B. Dow, F.F. Jen and K. Malik for their computational assistance.

3. Country Models generally take the foreign sector to be largely exogenous, and one which exhibits perfect competition. The demand for imports or supply of exports by the country being modeled is assumed not to affect the international prices of these commodities since most developing countries have a small share of the total market. Apart from the technical difficulties involved, where large scale models differ widely in scope, aggregation of country models would provide no assurance that the results will be consistent: the sum of the import and export price and volume estimates for a group of models would only fortuitously be in line with world demand and supply.

4. International Trade Models. Constructing a matrix of international trade flows, and distributing world imports and exports among countries according to past trade relationships, ensures that total world imports will equal total world exports, and that the estimated trade balances of a group of countries will be consistent with each other. However, the system begins to get unwieldy if it is broadened to include price effects and the feedback effects of exports on growth and imports. A more comprehensive approach has been attempted in Project LINK, starting with large econometric models of developed countries, and estimating an entirely consistent set of both national and international volumes and prices. At present, however, LINK lacks detailed models of the developing world, and its main thrust has been toward short term estimates of trade and growth rather than longer range projections. LINK's large size and short

term nature make it difficult to use for rapid policy simulations for long run projections as required by the Bank. In addition, LINK does not yet develop commodity details. 1/

5. Commodity Models. Examining world trade on a commodity by commodity basis is a very useful approach for working with LDCs, since most of their exports are primary products which are homogeneous in character and traded on world markets without differentiation as to source and destination. However, commodity models, like country models, are generally solved in isolation one from the other. This may be misleading for certain commodities with substantial substitution possibilities. A combination of commodity models would ensure that country price and volume projections for the commodities in question were consistent with the world market, but the diversity of existing models - using different dates and time periods, and with very different levels of aggregation - would present a major problem. 2/

II. The SIMLINK Approach

6. SIMLINK combines elements of all three of these approaches. In it, exports of the developing countries are related to the level of economic activity in the industrialized countries through a series of individual commodity models. Growth in the developing countries is linked to investment levels and imports; the latter, in turn, are tied to export earnings and the inflow of external

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1/ See R.J. Ball, ed. The International Linkage of National Econometric Models (North Holland, Amsterdam, 1973).

2/ For a survey of some commodity models and commodity modeling techniques, see W. Labys. Dynamic Commodity Models: Specification, Estimation and Speculation, (Lexington, Mass., 1973).

capital (as indicated by the real resource transfer, or balance on merchandise and non-factor services). The model may be run either to determine the import and GDP growth levels to be anticipated in developing countries, given a particular capital inflow and set of GDP growth rates in the OECD countries, or it may be run to determine the real resource transfer needed to support a specified target growth rate of GDP in developing countries, given expected developments in the OECD countries. It may be thought of as being block recursive in the following steps:

a) the rate of growth of output and prices in the developed world (largely the OECD countries) are taken as exogenously determined. Since the developing countries have little feedback effect on the developed world this is felt to be a reasonable assumption;

b) commodity models are developed or adapted for the major primary exports of the developing countries, to project prices and volumes for these products. The price of petroleum, however, is taken as exogenous;

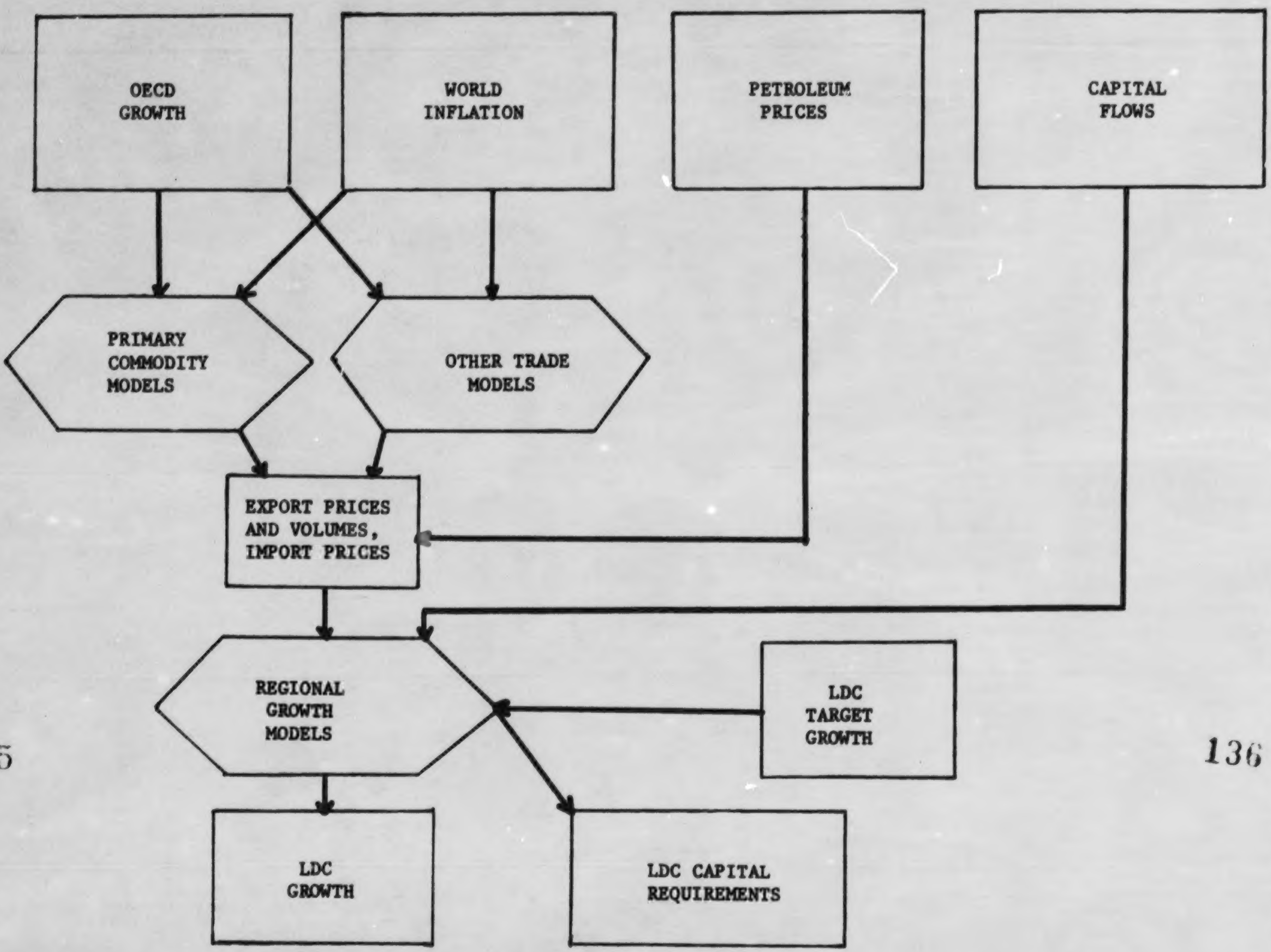
c) exports of manufactures and services from developing countries are projected on the basis of historically estimated elasticities with respect to OECD growth. Prices for these items are projected on the basis of exogenously forecasted rates of inflation in the OECD;

d) the commodity trade volumes and prices so calculated are translated into export volumes and both import and export prices, for seven groups of developing countries;

e) a simple growth model is developed for each of the seven groups, relating the growth of imports to growth of output and investment. These models are then solved for that level of GDP growth which equates total imports with the capacity to import, based upon exports, the terms of trade, and exogenously specified levels of capital inflow. They are also solved using exogenous target GDP growth rates, to give an estimate of the foreign capital required to meet those targets.

7. At present SIMLINK contains 14 commodity models with a total of about 79 structural equations; 11 equations for estimated exports of manufactures and services, and 7 regional models with 8 equations each. Ignoring definitional equations and identities, the model has a total of 146 structural equations. While comprehensive in nature, it thus remains simple enough to be calculated quickly. It is generally estimated using ordinary least squares techniques and is largely recursive in nature, though there is some simultaneity in certain parts, mainly related to the individual commodity models. Figure I gives a rough idea of the flow from the exogenous input to the output. The span of data used depends largely on availability; the estimated coefficients are based on data ranging over the past 6 to 20 years.

Fig.1.- FLOW DIAGRAM - SIMLINK III


OECD GROWTH
WORLD INFLATION
PETROLEUM PRICES
CAPITAL FLOWS
PRIMARY COMMODITY MODELS
OTHER TRADE MODELS
EXPORT PRICES AND VOLUMES, IMPORT PRICES
REGIONAL GROWTH MODELS
LDC TARGET GROWTH
LDC GROWTH
LDC CAPITAL REQUIREMENTS

III. The Model in Detail

8. The model starts with a data base for a sample panel of 40 developing countries which account for about 85% of the population of the developing market economies (excluding OPEC members). Based on 1973 data, the panel receive over 80% of the net disbursements on public loans and account for over 80% of the external public debt (outstanding and disbursed). Their share in the aggregate GNP of developing countries is slightly smaller - 76% in 1973. They account for 70% of the exports of developing countries in all regions except East Asia and the Mediterranean - in these two regions the trading role of a few non-sample panel countries (notably Singapore, Hong Kong and Spain) lowers the panel's coverage to about 61% (based on 1973 data). For the purposes of the model, the sample panel countries are aggregated into seven "regions" or groups, which are shown in Table 1.

A. Commodity Models

9. A matrix of export shares in 1972 for 35 primary products and for manufactures and services was constructed for these seven groups, from data compiled by the Commodities and Export Projections Division of the Bank 1/ and from U.N. Trade Yearbooks. Of the 35 primary products, only about 15 account for a substantial share of the exports of any one regional group. Models were developed first for the most important commodities (excluding petroleum), and are

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1/ See "Commodity Trade and Price Trends", IBRD Report No. EC-166/74, August 1974, and also Appendix I, Table 2 below.

Table 1: SAMPLE PANEL COUNTRY GROUPINGS

1. Low Income [a]

   a. South Asia (4)

      India
      Bangladesh
      Sri Lanka
      Pakistan

   b. East/Central Africa (6)

      Kenya
      Tanzania
      Uganda
      Ethiopia
      Mali
      Sudan

2. Middle Income

   a. Mediterranean (6)

      Egypt
      Syria
      Tunisia
      Greece
      Turkey
      Yugoslavia

   b. West Africa (5)

      Cameroon
      Ghana
      Ivory Coast
      Senegal
      Sierra Leone

   c. East Asia (4)

      Korea
      Philippines
      Thailand
      Malaysia

   d. Latin America (8)

      Argentina
      Brazil
      Colombia
      Dominican Republic
      Guatemala
      Mexico
      Peru
      Uruguay

   e. Mineral Producers (7) [b]

      Chile
      Bolivia
      Jamaica
      Liberia
      Morocco
      Zaire
      Zambia

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[a] 1971 per capita income less than $200.

[b] All mineral producers are in the middle income group except Zaire. Results for this "region" are divided among the two income groups according to Zaire's proportion of total GDP, imports, etc.

summarised in Table 2. Exogenous price and volume estimates have been used for a few important commodities for which it proved difficult to develop useful models, some of them, like wheat, cotton and tobacco, influenced in the past by U.S. surplus policies. Work is continuing in an attempt to expand the system to include both better models and models for commodities not presently covered.

10. Supply. It is difficult to summarize in a small space the work of different researchers on these eleven models. 1/ On the supply side, they assume a distributed lag response by producers to past prices, based on biological and information lags. The general form of the supply equation can be expressed as

$$Q_j = (P_{j_{t-1}}, P_{j_{t-2}},; \ldots P_{j_{t-n}}, Y, O_1, O_2, \ldots O_n) \qquad (1)$$

where Q is the supply of the j^{th} commodity, P_j is its real price lagged by an appropriate number of time periods, Y is real OECD GNP in 1963 dollars, and the O's are other variables. In most cases, total supply Q_j is the sum of two or more supply equations estimated on a regional or country basis in order to capture the different time lags apparent in different areas of the world. The lagged prices $P_{j_{t-2}} \ldots P_{j_{t-n}}$ were often dropped in favor of simple lagged supply, $Q_{j_{t-1}}$, thus introducing the assumption of a distributed lag with geometrically declining weights. 2/ In some cases, such as rice, where world prices are largely determined by exports and a large part of production is not exported, the model deals only with exports rather than total world production.

1/ Complete equations are given, along with their statistical properties, in Appendix II.

2/ For a discussion of the use of the lagged endogenous variables as a transform of the distributed lag equation, see Zvi Griliches, "Distributed Lags: A Survey", Econometrica, Vol. 35 (January 1967), p. 16.

The prices of substitutes were important in only a few commodity models: rice (wheat), tin (aluminum) and fats and oils (other fats and oils). Dummy variables were inserted to reflect unusual conditions present in certain years, many of which can be traced to weather fluctuations. Most of the models were estimated econometrically with annual time series data from the 1955-72 period, although the time period differs slightly in each model. In certain regions where no econometric relationship could be uncovered, an exogenous supply estimate has been used (see Table 2).

11. Demand. The price formation or demand side of the models was generally estimated in one of two ways. In some models, prices were estimated to be a direct function of world supply and demand, giving an equation of the following form:

$$P_j = f(Y, Q, O_1, O_2, \ldots O_n) \qquad (2)$$

where Y is total OECD GNP, Q is the total of world exports or production, and the O_i are other variables important in price determination (for example, the prices of substitutes, dummy variables, and the rate of world inflation). An alternative to the simple direct price formation equation (2) above is the slightly more complex stock adjustment approach. Here, the demand vector determines consumption of the commodity in question. Inventories or stocks are defined as current production less current consumption plus stocks from the previous year, and real prices are determined by the level of stocks (which may be expressed as an inverse relationship or as a ratio to total production).

This three-equation method of determining prices can be summarized as follows:

$$C_j = f\ (Y) \qquad (3)$$

$$S_j = S_{j_{t-1}} + Q_j - C_j \qquad (4)$$

$$P_j = f\ (S_j) \qquad (5)$$

where C_j stands for consumption and S_j for end year stocks, with only the lagged variables subscripted for time. Other variables may be included in the consumption and price equations, although these are not included in the notation above. Equations (3) to (5) can be reduced to equation (2) by substitution, so that by using equation (2) one is merely estimating directly a reduced form of the stock adjustment equation.

12. Sensitivity to Inflation. The P_j are estimated in real terms, by deflating current prices using the Bank's International Price Index (IPI). 1/ Since the supply equations are also related to real rather than current prices, most of the commodity models are found to be neutral in their response to changes in the rate of world inflation. Certain models -- coffee, sugar and rice -- were exceptional in that the index of world inflation was found to be an important independent variable. In general, the higher the rate of world inflation the lower the real prices of these commodities. 2/

1/ An index of prices of developed countries' manufactured exports to all destinations. See Table 7 below.

2/ This appears to confirm the hypothesis that developing countries suffer during periods of sharp world inflation because the prices of most of their exports fail to keep up with other prices. But it should be pointed out that the lag is somewhat temporary, and that eventually real prices tend to adjust. This suggests that perhaps sellers fail to note other world prices effectively, or that sales are made in advance of production and delivery and that acceleration of inflation rates is generally unexpected.

TABLE 2: Commodity Models Summary

Commodity	Author	No.of Equations		No.of Supply	No.of Exog.	Prices Related to:
		Total	Structural	Equations[2]	Supply Est.	
Iron Ore	F.Pinto	6	3	1	0	Exogenous.
Fats & Oils[1]	P.Pollak	25	24	0	12	OECD income, sugar exports, prices of substitutes.
Copper	F.Pinto	7	5	2	0	OECD income, lagged prices, mine production, lagged consumption.
Rice	N.Hicks	8	6	2	2	OECD income, rice exports, wheat price inflation.
Sugar	E.Brook/P.Pollak	15	13	7	0	Excess consumption - production ratio, lagged prices, food price inflation.
Beef	N. Hicks	6	5	4	0	Income W. Europe, production.
Tin	F. Pinto	5	4	1	0	Stocks: consumption, lagged prices, price of aluminum.
Cocoa	N. Hicks	9	7	5	1	OECD income, production, lagged stocks, lagged average prices.
Rubber	J. Gunning	7	6	4	1	Stock changes, lagged prices.
Tea	N. Hicks	3	3	1	0	Production, time trend.
Coffee	J. de Vries	13	10	6	0	Production, lagged prices stocks, inflation, lagged consumption.

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[1] Covers groundnuts, groundnut oil, copra, coconut oil, palm oil.

[2] Excludes exogenous supply estimates.

13. "Residual" Commodities. For primary products not covered by the existing commodity models, a more general formulation has been used to project volumes and prices. First, they are aggregated into three broad classes: food, agriculture non-food, and metals and minerals. Increases in the prices of these "residual" commodity groups are estimated using the following equation:

$$p' = -\frac{y' E_y - s'}{E_d} \qquad (6)$$

where p' is the percentage increase in price for the commodity group in question; y' is the growth rate of OECD real GNP; s' is an exogenous estimate of the growth rate of supply; and E_y and E_d are the respective income and price elasticities. The values of the parameters used in the model for this equation are given in the table below, and are based on estimates provided by the Commodities and Export Projections Division of the Bank.

Table 3

Residual Commodity Model Coefficients

Group	E_y	E_d	s'
Agric-Food	0.5	-.5	4.0
Agric-Nonfood	0.9	-.7	5.0
Minerals and Metals	1.1	-0.5	6.0

B. Manufactured Exports 1/

14. A slightly different approach is used for developing countries' manufactured exports. Firstly, since these countries account for a relatively small share of total manufactured exports, it is assumed that supply and demand are not reconciled via the price mechanism. Total demand by the OECD and centrally planned countries for manufactured exports from LDCs is allocated among the seven groups of sample panel countries according to market shares based on initial exogenous estimates of the growth of supply. To estimate income elasticities of demand, log-log regressions were run, using constant prices, between the GDP and manufactured imports from LDCs (regardless of source) of groups of OECD countries and the centrally planned economies. The data for these regressions are based on U.N. trade data and cover the period 1965-72. The results are summarized in Table 4 below:

Table 4

Income Elasticities for Imports of Manufactured Goods from Developing Countries

	E_y	t	$\bar{R}^2$
Japan/Oceania	2.24	7.4	.885
Western Europe	2.62	9.9	.933
North America	5.36	10.9	.943
Centrally Planned Economies	2.27	6.3	.849

1/ Here defined as SITC 5-8, excluding SITC 68 (non-ferrous metals)

15. These rather high elasticities have to be adjusted for two factors. First, they relate to 68 developing countries including Hong Kong, Singapore and Taiwan; and second, they obviously take no account of manufactured exports to other developing, rather than to developed, countries. So as to avoid overstating export demand, the export growth rate calaculated for the 40 sample panel LDCs between 1965 and 1972 -- 12.2% per annum is compared with the rate of growth of import demand in OECD countries (from all LDCs) for the same period -- 15.7% per annum -- both in constant prices. The ratio of these two growth rates (0.777) is used to adjust the original elasticities downward.

16. An estimate of the aggregate supply of manufactured exports from developing countries is used to arrive at the market shares of the seven regional groups, taking account of historical growth rates in constant prices for the period 1965-72. For two regions, South Asia and East/Central Africa, political events between 1970-72 meant that manufactured exports grew at lower than historical rates, so the growth rates for 1965-70 are used instead. These supply estimates; each region's share of total sample panel exports of manufactured goods, and the importance of manufactured goods in total exports from sample panel countries are shown in Table 5:

Table 5: Manufactured Exports by Sample Panel Groups

	(1) Growth Rate of Manufactured Exports (1965-72) (% p.a.)	(2) Distribution of LDC Manf. Exports (1972) (%)	(3) Manf. Exports Share of Total LDC Exports (1972) (%)
Mineral Producers	13.8	2.1	3.8
South Asia	5.4[a]	16.6	32.2
East Africa	6.0[a]	.8	3.5
Mediterranean	10.4	26.8	26.0
West Africa	7.2	2.1	8.9
East Asia	26.8	26.4	26.6
Latin America	19.8	25.2	14.9
Total: 40 LDCs	12.2	100.0	19.1

[a] for period 1965-70

17. Using the 1972 percentage distribution (column 2) a weighted average growth rate of supply of manufactures is calculated, and compared to the average growth rate of demand, weighted according to the shares of OECD and centrally planned country groups in total demand. The initial estimates of the growth rate of supply are then adjusted such that the growth rates of aggregate supply and demand are equal. Algebraically, if SM_i is the initial supply growth estimate for the i^{th} LDC region, and DM_j is the demand growth estimate for the j^{th} developed region, and wd_j and ws_i are the appropriate weights, the final export growth rate for the i^{th} region (XM_i) is given as:

$$XM_i = SM_i \frac{\left(\sum_{j=1}^{4} DM_j wd_j\right)}{\left(\sum_{i=1}^{7} SM_i \; ws_i\right)} \qquad (7)$$

C. Service Exports

18. Services are another very important source of export earnings in LDCs, but are often ignored in trade models due to the lack of data on an origin-destination basis. Data for non-factor service exports were obtained from the World Bank's Socio-Economic Data Bank, in current prices for each region for the period 1964-72. It was assumed, once again, that the OECD is the principal source of demand for these services, which include tourism, travel and shipping services.

19. As with manufactures, the OECD was disaggregated into three regions: North America, Western Europe, and Japan/Oceania. Regressions were then run to estimate demand elasticities with respect to the GNP of each of the OECD Regions, with the best estimate being used in the model. Since the observation period is relatively short, only single variable regressions were attempted. While the income of the Japan/Oceania region did not prove significant for any sample panel region, a combination of Japan/Oceania and North America did work well for three regions, with Western Europe proving best for another two, and total OECD accounting for the remaining two. The results are shown in Table 6 below. 1/

1/ Unlike the manufactured export regressions, the non-factor service regressions are done in current prices. In the model, the projected current price service exports are deflated by the implicit GNP deflator of the OECD countries to convert to constant prices.

Table 6: Exports of Services

LDC Group	Service Exports to Total Exports	GNP	E	t	$\bar{R}^2$
Mineral Producers	18.2	W. Europe	1.006	16.09	.974
South Asia	7.2	Total OECD	.448	8.54	.947
East/Central Africa	26.9	Total OECD	1.311	8.55	.911
Mediterranean	35.9	W. Europe	1.244	15.10	.970
West Africa	27.2	Total OECD	1.920	15.45	.971
East Asia	17.8	Japan and N. America	.959	4.59	.742
Latin America	23.6	Japan and N. America	1.288	28.89	.992

20. The estimated equations all show good fits with respect to their demand vectors, and all of the income elasticities are significant at the 95% confidence level or higher. It is interesting to note the wide differences in elasticities, from .45 for South Asia to 1.9 for West Africa. Areas with a highly developed tourism sector seem to have higher elasticities than those without, and this is probably the major factor explaining these regional differences. The 1.9 elasticity for West Africa appears to be unusally high and was probably influenced by the very rapid development of tourism in this region during the past few years. Consequently, this coefficient was lowered to 1.4 for projection purposes in the model.

D. Prices and Inflation

21. The consistency between current and constant price estimates is maintained by use of a series of international price deflators. The four main indices of world inflation that are used in the model are shown in Table 7. IPI is used both to inflate projected real

Table 7

Inflation Assumptions

1967-69=100

	IPD[1]		IPI[2]		IPICAP[3]		IPIXM[4]	
	Index	%age Change	Index	%age Change	Index	%age Change	Index	%age Change
1960	76.5	-	90.9	-	91.3	-	92.6	-
61	79.8	4.3	92.9	2.2	92.6	1.5	94.2	1.6
62	82.9	3.9	92.9	0.0	93.5	1.0	93.9	-0.2
63	86.4	4.2	93.6	0.7	95.1	1.7	94.5	0.5
64	89.4	3.5	94.7	1.2	95.9	0.8	95.3	0.8
65	92.6	3.6	96.4	1.8	96.8	0.9	97.0	1.8
66	95.2	2.8	98.4	2.1	98.8	2.1	98.7	1.8
67	97.8	2.7	99.4	1.1	99.7	1.0	99.5	0.8
68	99.1	1.3	98.4	-1.0	98.4	-1.3	98.4	-1.1
69	103.0	3.9	102.1	3.8	101.8	3.5	102.1	3.8
1970	110.2	7.0	109.4	7.1	109.0	7.1	108.9	6.1
71	120.6	9.4	116.5	6.3	118.0	8.2	114.4	5.1
72	135.4	12.3	126.6	8.8	129.1	9.4	121.2	5.9
73	149.2	13.5	149.6	18.2	147.9	14.5	144.7	19.4
74	164.0	9.9	182.2	21.8	171.8	16.1	178.2	23.2
75	183.7	12.0	202.0	10.8	191.0	11.2	199.6	12.0
76	201.7	9.8	219.9	8.8	208.5	9.2	219.1	9.8
77	218.8	8.5	237.5	8.0	225.6	8.2	237.7	8.5
78	236.4	8.0	255.4	7.5	242.9	7.7	256.7	8.0
79	254.1	7.5	274.6	7.5	261.1	7.5	276.0	7.5
1980	271.9	7.0	293.8	7.0	279.4	7.0	295.3	7.0

1/ An index of the implicit GNP price deflators, converted to U.S. dollars, of USA, France, Germany, Italy, Japan and U.K.

2/ An index of manufactured import prices for LDCs,based on SITC categories 5 through 8 (f.o.b. prices of manufactured exports of OECD countries to all destinations, adjusted for the freight component of c.i.f. costs).

3/ An index of capital goods (SITC 7 only) import prices for LDCs.

4/ An index of developed countries' manufactured export prices, basically the same as IPI but on a f.o.b. basis, and using LDC export weights.

NOTE: Based on U.N. trade indices for export prices from developed countries of SITC categories 5 through 8 (manufactures) and SITC 7 (capital goods). IBRD staff estimates of freight costs.

commodity prices to current prices and to serve as a price index for manufactured imports by developing countries. IPIXM is used to inflate the value of exports of manufactures from developed countries. IPD is used to convert the GNP growth of OECD countries from real to current terms, and to inflate the value of non-factor service imports and exports. IPICAP is used to inflate the value of exports of capital goods from developed countries.

22. For each of the seven sample panel regions, SIMLINK constructs an index of export value and export volume using the 1972 weights shown in Appendix I, Tables 1 and 2. Regional export price indices (XPI) are determined by the export value and volume indices: by using the XPI, real export prices are converted to current prices, and, using 1972 weights, the export price index is then calculated in current prices. Regional import price indices (MPI) are made up from series of 5 basic indices for each region, constructed on the basis of imports in 1972 divided by end-use class into food, intermediates, fuels, capital goods and non-factor services. The price indices for capital goods and non-factor services are based on assumed international inflation rates. The price index for fuels is assumed to equal that for petroleum. For food imports, a weighted price index is constructed using the commodity prices generated by the model. 1/ The weights used are based on an analysis of the composition of food imports of the larger developing countries.

1/ The commodities included and their weights are: wheat, 40%; rice, 15%; maize, 5%; sugar, 15%; tobacco, 5%; groundnut oil, 15%; and beef, 5%.

E. Regional Growth Models

23. The regional indices of export value, export volume and import prices are applied to 1972 base data in 1967-69 prices to derive estimates through 1980. Export values, expressed in constant dollars, are then adjusted for changes in the terms of trade to produce "exports-adjusted" (XADJ), so that they reflect true import-purchasing power. The adjusted exports for each region are defined as: 1/

$$XADJ = \frac{XPI}{MPI} X \qquad (8)$$

Where X represents exports in constant prices, and MPI and XPI are the relevant regional import and export price indices, respectively. Total import capacity (M_a) is then defined as the sum of XADJ and the capital inflow available, or resource gap (RG_a). Capital inflows are estimated exogenously, according to analyses of countries' creditworthiness and the availability of external capital. The term "capital" used here is defined as the net transfer of resources from foreign savings, or the "gap" between the cost of imports and foreign exchange earnings from exports of goods and non-factor services.

$$M_a = XADJ + RG_a \qquad (9)$$

1/ All variables are for period t and region i, unless subscripted differently.

Imports and Growth

24. Much discussion has taken place over the relationship between imports and growth, and the importance of foreign exchange versus other constraints in the developing world. 1/ Some authors have contended that there is no relationship, or that increases in imports (particularly those financed from increases in capital inflows) result in lower savings, higher consumption and no appreciable increase in growth. 2/ Such analyses have tended to examine imports in the aggregate, and their relationship to total GNP. In fact, LDC imports are a very non-homogeneous mixture of capital goods; intermediate products and raw materials; and foodstuffs and other consumer goods that are not related to capital formation and production. The imports of foodstuffs are often inversely correlated with growth, since they often supplement declines in domestic agricultural production. In most of the better country models, imports are disaggregated in some fashion, usually by end-use classes, and related either to sector outputs or some part of GNP expenditure.

1/ H. B. Chenery and Alan M. Strout, "Foreign Assistance and Economic Development", American Economic Review, LVI (Sept. 1966), pp. 680-733. J. C. H. Fei and Gustav Ranis, "Foreign Assistance and Economic Development: Comment, "American Economic Review," LVIII (Sept. 1968, pp. 897-912, Henry J. Bruton, "The Two-Gap Approach to Aid and Development: Comment, "American Economic Review, LIX (June 1969), pp. 439-446.

2/ K.G. Griffin and J.L. Enos, "Foreign Assistance: Objectives and Consequences", Economic Development and Cultural Change, XVLLL (April, 1970) pp. 313-27

25. Following the same approach, a general model of growth and imports was formulated along the following lines: First, industrial production is assumed to be a linear function of total GDP: 1/

$$YIND = a_1 + b_1\,GDP \qquad \text{(value added, industry)} \qquad (10)$$

Investment is a function of the increment to GDP and lagged investment, on the style of the flexible accelerator where the desired capital stock adjusts with a distributed lag. In this case the implied lag is of the Koyck type, or one having geometrically declining weights:

$$I = a_2 + b_{21}(GDP-GDP_{t-1}) + b_{22}I_{t-1} \qquad \text{(gross investment)} \qquad (11)$$

Imports of capital goods are then related linearly to investment; intermediate goods to value added in industry; and imports of fuels and non-factor services to total GDP, or:

$$MCAP = a_3 + b_3\,I \qquad \text{(imports, capital goods)} \qquad (12)$$

$$MINT = a_4 + b_4\,YIND \qquad \text{(imports, immediate products)} \qquad (13)$$

$$MFUEL= a_5 + b_5\,GDP \qquad \text{(imports, fuels)} \qquad (14)$$

$$MSER = a_6 + b_6\,GDP \qquad \text{(imports, non-factor services)} \qquad (15)$$

26. It was initially proposed to relate imports of food to private consumption and to agricultural production, and imports of other consumer goods to private consumption expenditures. However, in almost all cases the results of so doing were non-significant or had the "wrong" signs (in the case of food it can be expected that imports vary inversely with domestic production, and directly with consumption). It appears that imports in both these categories are

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1/ All a's are constant terms, and all b's are estimated coefficients.

heavily influenced by the level of foreign exchange available to finance them. The proxy for foreign exchange availabilities was taken to be the actual level of imports of goods, so that the combination of food plus other consumer goods imports was simply related to this variable: 1/

$$MCF = a_7 + b_7 \; MG \qquad (16)$$

Total (actual) imports of goods is defined as:

$$MG = MCAP + MINT + MFUEL + MCF \qquad (17)$$

and total import demand, at a given level of GDP, as:

$$M_d = MG + MSER \qquad (18)$$

where the d subscript denotes import demand, as opposed to the capacity to finance imports, M.

Two Versions of the Model

27. So far the discussion in this section has focussed on the availabilities version of the model, in which capital availabilities are exogenous. In this version, an equilibrium condition is enforced such that import demand must equal the capacity to import, or

$$M_d = M \qquad (19)$$

The model is then solved for that level of GDP and GDP growth which will satisfy this condition.

1/ In South Asia and East/Central Africa exogenous estimates of MCF are used, based on a projected increase in foodgrain imports and constant imports of other foods and consumer goods. In the base case, a growth rate of 3.5% is used for foodgrain imports in both regions.

28. In the requirements version, target GDP growth rates (g) are specified exogenously for each region:

$$GDP_t = GDP_{t-1}\ (1+g) \qquad (20)$$

The capital inflow that is required to support such a growth rate (RG_r) is determined as the difference between import demand and the capacity to finance imports, based on export earnings:

$$RG_r = M_d - XADJ \qquad (21)$$

29. Hence the requirements version drops equations 9 and 19 from the model and uses 20 and 21 to determine a capital inflow endogenously from a predetermined growth level. The additional capital requirement (ACR) is defined as the difference between the capital available and that required to attain the growth target:

$$ACR = RG_r - RG_a \qquad (22)$$

or:

$$ACR = M_r - M_a \qquad (23)$$

Savings Rate

30. Domestic savings (GDS) can be determined residually from the identity:

$$GDS = I - RG$$

This residual determination of savings is the necessary consequence of the structure of the model which considers foreign exchange, rather than savings, capital or labor, as the binding constraint on growth in the developing world. While this is a serious simplification, since the model is being used to project over a period when deteriorating terms of trade and low export volume growth will

TABLE 8 : SUMMARY OF REGIONAL MODEL REGRESSIONS

	MCAP = $a_3 + b_3$ I			MINT = $a_4 + b_4$ YIND			MFUEL = $a_5 + b_5$ Y			MCF = $a_7 + b_7$ MO		
	a_3	b_3 (t)	$\bar{R}^2$	a_4	b_4 (t)	$\bar{R}^2$	a_5	b_5 (t)	$\bar{R}^2$	a_7	b_7	$\bar{R}^2$
Mineral Producers	307.5	.3120 (4.85)	.505	337.3	.2371 (3.6)	.301	-2015	.0255 (4.2)	.429	75.8	.2462 (5.73)	.588
South Asia		.111$^{a/}$			.128$^{a/}$		-384.6	.0089 (4.04)	.539		exogenous	
East Africa	62.2	.2773 (8.0)	.646	84.6	.4322 (5.14)	.430	-3.2	.0077 (3.17)	.223		exogenous	
Mediterranean	-420.6	.2731 (10.2)	.746	160.7	.217 (7.84)	.637	-135.0	.0128 (6.69)	.561	156.9	.178 (10.0)	.741
West Africa	178.0	.2069 (4.12)	.414	285.4	.2449 (3.93)	.392	7.5	.0068 (1.46)	.082	22.3	.3088 (10.5)	.821
East Asia	-55.2	.3423 (7.11)	.727	684.5	.3275 (5.53)	.617	-432.6	.0376 (9.22)	.817	-185.1	.2615 (13.4)	.904
Latin America	-1377.3	.2365 (18.8)	.929	-282.2	.1179 (7.89)	.697	-262.0	.0071 (4.58)	.437	515.5	.1174 (5.85)	.559

	$I = a_2 + b_{21} (Y_t - Y_{t-1}) t b_{22} I_{t-1}$				YIND = $a_1 + b_1$ Y			MSER = $a_6 + b_6$ Y$^{c/}$		
	a_2	b_{21} (t)	b_{22} (t)	$\bar{R}^2$	a_1	b_1 (t)	$\bar{R}^2$	a_6	b_6 (t)	$\bar{R}^2$
Mineral Producers	504.3	.5129 (1.38)	.7335 (3.94)	.854	-1010.5	.2994 (7.80)	.726	-350.0	.078 (5.42)	.780
South Asia	-397.9	.1537$^{b/}$ (8.99)		.869	-7860.6	.3035 (8.69)	.844		.0083$^{a/}$	
East Africa	-125.2	.1805$^{b/}$ (5.09)		.757	-5061.2	.3339 (30.9)	.972	- 13.0	.040 (4.28)	.684
Mediteranean	-164.4	.4763 (2.34)	.9653 (8.03)	.971	--4664.0 (2.49)	.4049	.947	-452.0	.036 (47.59)	.997
West Africa	77.4	.8678 (2.97)	.6649 (2.46)	.608	-101.6	.1823 (6.71)	.652	-194.	.106 (8.74)	.915
East Asia	702.3	.6358 (4.10)	.7323 (7.77)	.943	-2099.7	.3058 (19.18)	.951	-154	.037 (4.72)	.727
Latin America	-391.2	.5473 (6.60)	.9193 (21.0)	.999	-5061.2	.3339 (30.9)	.972	-341	.026 (8.62)	.902

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a/ Based on average of 1969-71.

b/ Investment function for South Asia and East Africa: $I = \alpha + BY$

c/ Equations for MSER are estimated in 1967-69 constant prices.

squeeze foreign exchange earnings, it is considered acceptable. The ex post calculation of the savings rate allows for the qualitative judgement that such a rate is realistic, and that a savings constraint is not binding.

Regression Results

31. The estimated equations are given in Table 8. In general, these equations were estimated on the basis of pooled cross-section and time series data for the period 1966 to 1971, although the exact time period differs slightly from region to region. The time period used is short because of the shortage of data on imports by end-use. The data used here are derived from the United Nations Trade Yearbook, allocated to end-use classes on a two digit SITC level. The data for individual countries in each region were pooled together for estimates of the region, using the technique of including an individual constant term for each country. This increases the degrees of freedom and offsets the shortness of the observation period. While the R^2 of the estimated equations is low, almost all of the estimated coefficients are significant at the 95% level. The low R^2 can be attributed in part to the fact that cross-sectional coefficients are found in the regressions for imports of services, since these are based on straight time series data.

32. Major problems arose with the regressions for South Asia; the past history of that region with recurring natural disasters and wars makes almost all of the regressions non-significant. Data for the period 1968-71 were used to estimate coefficients based on simple averages. This implies import elasticities will be close

to unity, but this was not felt to be far from the truth for that region. In both South Asia and East/Central Africa the apparent stability of investment in the face of unstable output made it necessary to substitute an investment function based on total income, rather than on incremental income and lagged investment.

33. To check the validity of the estimates obtained from SIMLINK, the preliminary results were compared with projections made independently for the 40 countries of the sample panel, aggregated into the same 7 groups. These projections are based on country models which though not consistent with international demand forecasts do contain more information on individual country performance. These models can also provide detailed balance of payments projections, covering aspects of debt servicing and creditworthiness which SIMLINK does not handle. Most of the adjustments made to SIMLINK are the result of these comparisons.

IV. Assumptions

A. OECD Growth

33. The model has been run using three alternative assumptions as to GDP growth in the developed world - largely the OECD countries. These are based on an analysis of possible time paths of recovery from the 1974-75 recession. The "high" OECD growth case assumes a return to full capacity - full employment by 1977-78, followed by "normal" growth thereafter. Thus the annual average growth rate between 1975 and 1980 is 6.1%, while that between 1974 and 1980,

including the major recession year of 1975, is 4.9%. 1/ The "low" growth case assumes a longer period of recovery, whereby full employment is not reached until after 1980, and annual growth averages 4.6% between 1975 and 1980 and 3.5% between 1974 and 1980. These two possibilities are considered equally likely, and to facilitate exposition an average of the two, "medium OECD growth" is used in the base case and in the sensitivity tests, i.e. 4.1% p.a. between 1974 and 1980.

Table 9: Alternative Assumptions: Rates of Real Growth of GDP in Developed Countries

(percent per annum)

	1973	1974	1975	1976	1977	1978	1979	1980
"High":								
Japan/Oceania	9.5	-.3	1.2	8.8	7.4	7.4	7.0	6.8
Western Europe	5.3	2.2	1.3	4.6	6.4	5.7	5.0	4.8
North America	6.0	-1.7	-4.0	5.3	6.5	6.7	6.5	6.5
OECD Total	6.1	- .4	-.5	5.4	6.5	6.4	6.0	5.9
Centrally Planned Economies	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
"Low":								
Japan/Oceania	9.5	-.3	1.2	7.5	6.1	6.2	5.8	5.8
Western Europe	5.3	2.2	1.3	2.7	4.2	4.2	4.2	4.2
North America	6.0	-1.7	-4.0	5.0	4.5	4.5	4.5	4.5
OECD Total	6.1	-.4	-1.5	4.3	4.5	4.6	4.5	4.5
Centrally Planned Economies	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

1/ All growth rates quoted in this paper are compound growth rates between the indicated end points, i.e. 3.5% is the growth rate from end 1974 to end 1980, and thus does not include growth in 1974.

B. Petroleum Prices

34. Two assumptions as to the price of petroleum have been used in simulations of the model. The basic assumption is that the price of petroleum (Saudi Arabian light crude, f.o.b. Ras Tanura) remains constant in 1974 prices at U.S.$9.40 per barrel through 1980. The alternative assumption allows for a gradual decline in the real price to U.S.$7.50 per barrel (1974 = 100) by 1980. See Table 10 below:

Table 10

Alternative Petroleum Price Assumptions
(US dollars per barrel, f.o.b. Ras Tanura)

	1973	1974	1975	1976	1977	1978	1979	1980
Case I: "Constant" Price								
In current $	2.70	9.77	10.46	11.38	12.30	13.22	14.21	15.21
In 1974 $	3.27	9.77	9.40	9.40	9.40	9.40	9.40	9.40
Case II: Declining Price								
In current $	2.70	9.77	10.46	10.90	11.12	11.25	11.34	12.14
In 1974 $	3.27	9.77	9.40	9.00	8.50	8.00	7.50	7.50

The "constant" price alternative is consistent with OPEC's announced intentions to index petroleum prices to world inflation and to equilibrate supply and demand by controlling supply. It is used in the base case with the medium OECD growth assumption.

C. Inflation

35. Forecasts of international inflation are difficult to make but are necessary to run the model. The forecasts used are based on projections of internal and trade prices for OECD countries (see Table 7 above). Recent years have seen a sharp difference between domestic and trade inflation rates, with the latter accelerating more rapidly (and reversing the previous long term trend). In addition, c.i.f. and f.o.b. prices have diverged sharply, reflecting increased transport costs resulting from higher petroleum prices. In general, the price forecasts indicate a gradual decline in the international inflation rate to about 7.0% p.a. by 1980.

D. Capital Flows

36. As was noted in Section IIIE above, inflows of external capital are estimated exogenously for the"availabilities" version of the model. The estimates used are built up from projections made by Bank staff for each of the sample panel countries (using the country models referred to on p.27), and aggregated to regional totals. They are essentially estimates of "demand", in that they measure the projected gap between import requirements and export earnings, rather than the projected availability of foreign capital. However, it appears that the estimates used are roughly consistent with projected flows of official and private capital from developed countries.

37. The estimates are made in current prices and deflated using the import price index [1] of each region. Since it has been assumed that aid disbursements are not adjusted to world inflation (i.e. that the nominal flows are fixed)[2] any change in the rate of inflation assumed will also change the estimate of real capotal flows. Table 11 shows the assumptions for each region.

Table 11

Net Capital Flow[1] Assumptions
1973-80

(US millions $)[2]

	1973	1974	1975	1976	1977	1978	1979	1980
Mineral Producers	56	304	307	272	425	251	63	450
South Asia	1,304	3,632	3,658	4,344	4,517	4,565	4,829	5,156
East Africa	55	725	573	483	546	598	650	708
Mediterranean	4,008	6,572	7,470	8,092	8,825	9,915	10,888	11,457
West Africa	-37	13	265	211	244	223	225	203
East Asia	-280	2,370	3,678	2,512	2,497	2,460	2,606	2,483
Latin America	143	8,322	7,322	6,645	6,296	5,819	4,803	3,585
Total:	5,249	21,974	23,273	22,559	23,350	23,831	24,064	24,042

1/ From official and private sources
2/ Current dollars

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[1] See Section IIID above.

[2] Though this may appear somewhat extreme, the opposite approach using fixed real flows is considered even less realistic.

E. LDC Growth Targets

38. The "requirements" version of the model was run using a target rate of GDP growth of 6% p.a., for all the sample panel countries, for the period 1974-1980. This implies a growth rate of only 5.8% for the decade 1970-1980, which is somewhat short of the target set for the U.N. Second Development Decade (UNDDII). [1] On the basis of past performance, an average growth rate of 5.0% p.a. was proposed for the low income countries, and of 6.4% p.a. for the middle income countries, between 1974-1980. Table 12 shows the regional targets established:

Table 12

Target GDP Growth Rates
(% p.a.)

Region	1974-80
Mineral Producers	6.0
South Asia	4.9
East/Central Africa	5.4
Mediterranean	7.3
West Africa	6.5
East Asia	6.9
Latin America	6.0
Low Income	5.0
Middle Income	6.4
Total - Non OPEC	6.1

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[1] General Assembly resolution 2626 (XXV) of 24 October 1970, International Development Strategy for the Second United Nations Development Decade.

F. Exports to OPEC Countries

39. Because the SIMLINK model is estimated using data for a period when the OPEC countries were relatively unimportant in world trade, it assumes that OPEC imports will not be above their 1974 level in the years to 1980. Projections of imports of goods and non-factor services by these countries are taken from the Bank's SIMRICH model. In 1972, the 40 sample panel countries accounted for only 5.9% of all OPEC imports (excluding military goods) 1/, but if they can maintain this share in future, as is assumed here, it could become an important source of export earnings. The OPEC countries' projected imports vary with their earnings forecasts, which in turn vary according to petroleum prices and OECD growth rates (which determine export volume). Table 13 shows the values of exports to OPEC from the sample panel countries under alternative oil price and OECD growth assumptions.

Table 13

Sample Panel Countries' Exports to OPEC
(million US$)

OECD growth: Oil Price:	high "constant"	low "constant"	high declining	low declining
1972	1,089	1,089	1,089	1,089
73	1,457	1,457	1,457	1,457
74	2,904	2,904	2,904	2,904
75	3,925	3,925	3,925	3,925
76	4,517	4,479	4,498	4,461
77	5,829	5,636	6,452	5,364
78	7,272	6,846	6,452	6,124
79	8,626	7,939	7,261	6,763
80	9,806	8.868	7,918	7,274

1/ All developing countries accounted for closer to 14% of this total. It is conceivable that the LDCs' share of the OPEC market may expand or contract during the projection period. Since there are arguments on both sides, it was considered best to assume that the sample panel's share remains constant at 5.9%.

V. Results of Simulations

40. This chapter describes simulations using the base case (medium OECD growth at 4.1%, oil price constant at $9.40 in 1974 $) in some detail, and compares the results with those using the other OECD growth and oil price assumptions. Section B describes alternative simulations which show possible ways in which developing countries can achieve higher GDP growth rates. Detailed results are given in Appendix III.

A. Exports, Growth and Capital Requirements

41. As Table 14 shows, exports of primary products are relatively insensitive to growth in the developed countries.

Table 14

Export Volume Growth Projections by Commodity Class 1974-80

(% p.a.)

	High OECD Growth	Medium OECD Growth	Low OECD Growth
Agriculture (food)	3.0	2.9	2.9
Agriculture (non-food)	3.7	3.6	3.6
Minerals & Metals	4.9	4.6	4.3
Petroleum & Fuels	10.0	10.0	10.0
Manufactures	15.2	13.2	11.0
Services	6.9	6.2	5.5

Exports of manufactured goods from developing countries are much more sensitive: with high OECD growth, export volume expands at 15% per year, and with low, at only 11%. Exports of services are also fairly elastic with respect to OECD growth.

APPENDIX I

Table 1

Sample Panel Countries' Import Composition

(1972,millions $)

Regional Group		Food and Food Products	Inter-mediate Goods	Fuels	Capital Goods	Consumer Goods	Total
Mineral Producers	$	701	1256	207	1307	1685	5155
	%	13.6	24.4	4.1	25.4	32.7	
South Asia	$	889	1736	260	1029	254	4168
	%	21.3	41.7	6.2	24.7	6.1	
East/Central Africa	$	180	626	63	489	206	1564
	%	11.5	40.0	4.1	31.3	13.2	
Mediterannean	$	1045	3631	479	2956	654	8765
	%	11.9	41.4	5.5	33.7	7.5	
West Africa	$	236	452	59	339	193	1279
	%	18.4	35.3	4.6	26.5	15.1	
East Asia	$	826	2578	624	2012	628	6667
	%	12.4	38.7	9.4	30.2	9.4	
Latin America	$	932	4197	755	4749	956	11589
	%	8.0	36.2	6.5	41.0	8.2	
Total:	$	4809	14476	2447	12881	4576	39189
	%	12.3	36.9	6.2	32.9	11.7	

APPENDIX I

Table 2

Export Shares by Regional Groups
1972

Export	Mineral Prod.	South Asia	East Afr.	Mediterannean	West Afr.	East Asia	Latin America
Primary Products:							
Beef	.000	.000	.002	.009	.000	.000	.058
Cocoa	.001	.000	.000	.000	.183	.043	.006
Coconut Oil	.000	.006	.001	.000	.000	.011	.000
Coffee	.011	.010	.190	.000	.119	.028	.121
Copper	.395	.000	.008	.000	.000	.027	.016
Copra	.000	.002	.000	.000	.000	.014	.000
Cotton	.002	.023	.168	.084	.007	.000	.027
Groundnuts	.000	.002	.020	.001	.002	.001	.001
Groundnut Oil	.000	.000	.000	.000	.035	.001	.003
Iron Ore	.051	.042	.000	.000	.006	.003	.022
Jute	.000	.140	.000	.000	.000	.007	.000
Maize	.000	.000	.003	.001	.000	.011	.015
Palm Oil	.004	.000	.000	.000	.007	.016	.000
Petroleum	.019	.006	.000	.029	.008	.043	.013
Rice	.000	.011	.002	.006	.000	.026	.001
Rubber	.011	.011	.000	.000	.004	.079	.001
Sugar	.010	.010	.001	.004	.000	.029	.049
Tea	.000	.111	.046	.001	.000	.000	.001
Timber	.005	.002	.004	.010	.107	.069	.006
Tin	.026	.000	.000	.000	.000	.058	.001
Tobacco	.001	.028	.023	.033	.001	.007	.008
Wheat	.000	.000	.001	.002	.000	.000	.008
Other Agriculture (Food)	.095	.115	.157	.162	.094	.029	.192
Other Agriculture(Non-Food)	.007	.068	.067	.000	.008	.054	.033
Other Minerals & Metals	.143	.019	.003	.038	.058	.000	.035
Manufactures	.038	.322	.035	.260	.089	.266	.149
Non-Factor Services	.182	.072	.269	.359	.272	.178	.236
Total Exports (in millions $)	4579	4225	1828	8453	1959	8110	13878

Note: Total shares may not add to 1.0 due to rounding.

APPENDIX II

Commodity Models

This appendix gives the detailed commodity models used in SIMLINK-III, along with their econometric properties. While each model uses slightly different notation, the following are common to all:

Exogenous Variables:

IPI - International Price Index
Y63 - GNP of the OECD countries in constant 1963 $.

Endogenous Variables:

RP = real price in 1974 US $
Q = quantity produced
X = quantity exported
S = stocks

All variables are for current time period unless subscripted otherwise.

BEEF (N. Hicks/ R. Hunt):

$$QNA = -769.4 + \underset{(4.21)}{20.24}\ RPB_{t-1} + \underset{(4.63)}{16.92}\ RPB_{t-4}$$

$\bar{R}^2 = .858$ DW= 2.32 1959-72

Production, North America
'000 metric tons

$$QEU = 2861.6 + \underset{(6.30)}{12.13}\ RPB_{t-3}$$

$\bar{R}^2 = .749$ DW= 1.31 1959-72

Production, Europe
'000 metric tons

$$QLA = 4883.2 + \underset{(3.36)}{8.549}\ RPB_{t-3} + \underset{(2.23)}{6.074}\ RPB_{t-4} \underset{(2.38)}{-23.62}\ RPWH_{t-1}$$

$\bar{R}^2 = .860$ DW= 1.55 1959-72

Production, Latin America
'000 metric tons

$$QOTH = 7871.6 + \underset{(11.56)}{381.6}\ T + \underset{(1.49)}{5.077}\ RPB_{t-2}$$

$\bar{R}^2 = .970$ DW= 2.02 1959-72

Production, all other
'000 metric tons

$$QB = QNA + QEU + QLA + QOTH$$

Production, total

$$RPB = 799.3 - \underset{(8.88)}{7.0047}\ (QB/YEU)$$

$\bar{R}^2 = .821$ DW= 1.10 1955-72

Real price, beef, U.S.¢/kg

Exogenous:
T= time trend, 1955= 1
YEU= GNP Europe, 1963 U.S.$
RPWH= real price wheat, 1974 prices

COCOA (N. Hicks/ P. Yeung):

$$RPC = 164.3 - \underset{(3.26)}{.45125}\,MAPC - \underset{(4.28)}{6.7448}\,MS_{t-1} - \underset{(8.18)}{.1011}\,QC + \underset{(5.61)}{.0533}\,Y63$$

$$\bar{R}^2 = .867 \qquad DW = 2.27 \qquad 1955\text{-}73$$

real price cocoa
(U.S.¢/pound)

$$MS = .3692 + \underset{(7.61)}{221.1}\,(1/RPC)$$

$$\bar{R}^2 = .760 \qquad DW = .879 \qquad 1955\text{-}73$$

months stocks
('000 long tons)

$$QCNI = 84.68 + \underset{(3.07)}{1.183}\,RPC_{t-17} + \underset{(2.09)}{4.324}\,T$$

$$\bar{R}^2 = .769 \qquad DW = 1.86$$

Production, Nigeria
('000 long tons)

$$QCGH = 94.18 + \underset{(3.60)}{3.077}\,AP12 + \underset{(2.89)}{7.307}\,T$$

$$\bar{R}^2 = .653 \qquad DW = 1.51$$

Production, Ghana
('000 long tons) Uses 5 year moving average of prices centered on a 12 yr. lag

$$QCCA = 45.15 + \underset{(2.12)}{.16328}\,RPC_{t-17} + \underset{(6.57)}{2.701}\,T$$

$$\bar{R}^2 = .909 \qquad DW = 1.98$$

Production, Cameroon
('000 long tons)

$$QCIV = 33.40 + \underset{(9.67)}{8.212}\,T$$

$$\bar{R}^2 = .837 \qquad DW = 1.70$$

Production, Ivory Coast
('000 long tons)

$$QCR = 199.6 + \underset{(9.21)}{6.6158}\,T$$

$$\bar{R}^2 = .823 \qquad DW = 2.10$$

Production, rest of world
('000 long tons)

$$QC = QCNI + QCGH + QCCA + QCIV + QCR + QX$$

Production, total

$$MAPC = (RPC_{t-1} + RPC_{t-2} + RPC_{t-3})/3$$

Moving average price

$$AP12 = (RPC_{t-10} + RPC_{t-11} + RPC_{t-12} + RPC_{t-13} + RPC_{t-14})/5$$

Exogenous:

T= time trend, 1955= 1
QX= extra output from improved productivity
(= 30 long tons in 1975 rising to 150 by 1980)

Coffee Model: Equations 1947/48-1972/73 (Jos. de Vries)

1.
$$\log Q_t^{br} = 0.69262 + \underset{(1.36)}{0.32609} \log QAV_{t-7}^{br} + \underset{(4.32)}{0.44386} \log PAV_{t-7} + \underset{(fixed)}{0.2} \log P_{t-1}$$
$$- \underset{(2.02)}{014601} \log (Q_{t-1}^{br}/Q_{t-2}^{br}) - \underset{(1.96)}{0.46559} \left(\frac{S_{t-7}^{prod} - S_{t-12}^{prod}}{QAV_{t-7}^{br}}\right)$$
$$- \underset{(3.05)}{0.36152} D1_t^{br} - \underset{(6.60)}{0.83875} D2_t^{br}$$

R^2 = .840 DWS = 1.888

2.
$$\log Q_t^{col} = 1.45585 + \underset{(5.73)}{0.55961} \log QAV_{t-7}^{col} + \underset{(4.21)}{0.17612} \log PAV_{t-7} + \underset{(fixed)}{0.03} \log P_{t-1}$$
$$+ \underset{(1.58)}{0.02527} D1_t^{col}$$

R^2 = .800 DWS = 1.578

3.
$$\log Q_t^{sam} = -5.2557 + \underset{(16.07)}{0.95693} \log QAV_{t-7}^{sam} + \underset{(9.02)}{0.45997} \log PAV_{t-7} + \underset{(0.77)}{0.06199} \log P_{t-1}$$
$$- \underset{(2.24)}{0.24549} \log (Q_{t-1}^{sam}/Q_{t-2}^{sam})$$

R^2 = .962 DWS = 2.065

4.
$$\log Q_t^{nam} = - 0.63024 + \underset{(23.44)}{0.82343} \log QAV_{t-7}^{nam} + \underset{(5.74)}{0.13676} \log PAV_{t-7} + \underset{(0.90)}{0.03019} \log P_{t-1}$$
$$- \underset{(3.36)}{0.34088} \log (Q_{t-1}^{nam}/Q_{t-2}^{nam})$$

R^2 = .982 DWS = 1.725

5.
$$\log Q_t^{afr} = - 3.40738 + \underset{(28.57)}{0.76647} \log QAV_{t-7}^{afr} + \underset{(10.48)}{0.43605} \log PAV_{t-7} + \underset{(2.08)}{0.12335} \log P_{t-1}$$

R^2 = .988 DWS = 2.275

6.

$$\log Q_t^{as} = -4.34392 + \underset{(6.49)}{0.85623} \log QAV_{t-7}^{as} + \underset{(2.40)}{0.43288} \log PAV_{t-7} + \underset{(fixed)}{0.1} \log P_{t-1}$$

$$- \underset{(4.95)}{0.59811}\, D1_t^{as} + \underset{(1.74)}{0.40167}\, D2_t^{as}$$

$R^2 = .942 \quad DWS = 1.422$

7.

$$Q_t = Q_t^{br} + Q_t^{col} + Q_t^{sam} + Q_t^{nam} + Q_t^{afr} + Q_t^{as}$$

8.

$$S_t^{prod} = S_{t-1}^{prod} + Q_{t-1} - C_{t-1} + SEV_{t-1}$$

9.

$$P_t = -300.2 + \underset{(9.47)}{0.51296} P_{t-1} + \underset{(10.59)}{2162.3} \frac{C_{t-1} + C_{t-2}}{S_t^{prod} + Q_t} - \underset{(6.28)}{1.01405} \left(\frac{I_t - I_{t-2}}{I_{t-2}}\right) P_{t-1}$$

$$+ \underset{(2.32)}{449.7}\, DIC_t$$

$R^2 = .960 \quad DWS = 2.599$

10.

$$\log C_t^{prod} = 2.41447 - \underset{(7.88)}{906}\, 10^{-11} (P_{t-1})^2 + \underset{(19.42)}{0.77738} \log Y_t^{oecd}$$

$R^2 = .965 \quad DWS = 2.685$

11.

$$C_t^{usa} = 22{,}909 - \underset{(10.09)}{0.25274.10^{18}} (Y_t^{usa})^{-4} - \underset{(14.10)}{0.646} P_t + \underset{(2.65)}{912.44} (P_t/P_{t-1})$$

$$+ \underset{(3.46)}{583.66} \exp(-0.1(t-16)^2)$$

$R^2 = .960 \quad DWS = 1.767$

12.

$$\log C_t^{other} = 14.3071 - \underset{(51.78)}{54.7014} (Y_t^{other})^{-0.325} - \underset{(9.54)}{0.26165} \log P_t + \underset{(5.69)}{0.14552} (S_{t+1}^{usa}/S_t^{usa}$$

$R^2 = .995 \quad DWS = 2.519$

13.

$$C_t = C_t^{prod} + C_t^{usa} + C_t^{other} + (S_{t+1}^{usa} - S_t^{usa})$$

Coffee Model: Symbols Used

Q_t : Total harvested production of coffee in thousands of 60 kg bags. 1947/48: t=1

Regions : br = Brazil
col = Colombia
sam = South America excluding Brazil and Colombia
nam = North America
afr = Africa
as = Asia and Oceania

QAV_t : The five year weighted moving centered average of Q_t:
$QAV_t = 0.25\ Q_{t-2} + 0.75\ Q_{t-1} + Q_t + 0.75\ Q_{t+1} + 0.25\ Q_{t+2}$ /1

P_t : Real price of coffee, in US¢ per 100 pounds, unit value of US imports (f.o.b.).

PAV_t : The three year moving centered average of P_t: /1

I_t : Index of US wholesale prices, 1967= 100.

Y_t^{usa} : GNP of USA at market prices in hundreds of millions of 1963 constant US\$. 1947: t=1

Y_t^{other} : GNP at market prices of OECD countries other than the USA, in hundreds of millions of 1963 constant US\$.

C_t^{prod} : Domestic consumption of coffee in producing countries, in thousands of 60 kg. bags.

C_t^{usa} : Net Civilian Visible Disappearance of coffee in the USA, in thousands of 60 kg. bags.

C_t^{other} : Consumption in importing countries other than the USA, as measured by total exports from producing countries minus US Net Civilian Visible Disappearance and minus the increase in US inventories. In thousands of 60 kg. bags.

/1 To simplify calculations division by 3 has been omitted.

C_t : World disappearance of coffee, as measured by total exports from producing countries plus domestic consumption in those countries. In thousands of 60 kg. bags. 1947/48: t=1

S_t^{prod} : Beginning of period stocks in producing countries, in thousands of 60 kg. bags. 1947/48: t=1

S_t^{usa} : Beginning of period inventories of green coffee in the USA, in thousands of 60 kg. bags. 1947/48: t=1

$D1_t^{br}$: Dummy variable to capture the effects of Brasilian frosts in 1953 and 1955. It is unity in 1954/55 and 1956/57, and zero in all other years.

$D2_t^{br}$: Dummy variable to capture the effects of Brazilian frosts in 1963 and 1969. It is unity in 1964/65 and 1970/71. and zero in all other years.

$D1_t^{col}$: Dummy variable to capture the effect of the biennial cycle in Colombia. It is nil in non-cyclical years (t=4-8, 25 and 26), -1 in "off years" (t=1,3,10,12,14,16,18,20,22,24) and 1 in "on years" (all other years).

$D1_t^{as}$: Dummy variable to capture the direct effects of the war in Indonesia on production in Asia and Oceania. It is unity from 1947/48 through 1949/50, and zero in all other years.

$D2_t^{as}$: Dummy variable to correct for the underestimation of past production capacity by lagged production for the Asia and Oceania region due to the war in Indonesia. It is 0.5 in 1947/48 and 1956/57, unity in the intervening years, and zero in all other years.

DIC_t : Dummy variable to capture the effect of the establishment of ICO on prices. It is unity in 1963/64 and 1964/65, 0.5 in 1965/66 and 1966/67, and zero in all other years.

COPPER (F. Pinto/ K. Takeuchi)

$$USMP = \underset{(7.97)}{.7123\ USMP_{t-1}} + \underset{(3.95)}{.0264\ RPCU} - \underset{(4.73)}{294.9\ DUM1}$$

$\bar{R}^2 = .844$ DW = 1.95 1953-73

U.S. Mine Production
'000 metric tons

$$RWMP = \underset{(34.5)}{.9763\ RWMP_{t-1}} + \underset{(2.8)}{.1303\ RPCU_{t-4}}$$

$\bar{R}^2 = .988$ DW = 1.53 1953-73

Mine Production, rest of world
'000 metric tons

$$MP = USMP + RWMP$$

Mine Production, total
'000 metric tons

$$CR = \underset{(3.13)}{.5776\ CR_{t-1}} + \underset{(3.19)}{1.989\ Y63_{t}} - \underset{(2.88)}{.2497\ RPCU_{t-1}}$$

$\bar{R}^2 = .979$ DW = 1.70

Refined Copper Consumption
'000 metric tons

$$PR = \underset{(51.7)}{1.059\ MP} + \underset{(5.4)}{.2528\ RPCU_{t}}$$

$\bar{R}^2 = .992$ DW = 1.27

Refined Copper Production
'000 metric tons

$$TPR = PR + DUMRP$$

Total Production, adjusted

$$TCR = CR + DUMRC$$

Total Consumption, adjusted

$$RPCU_{t} = 6817.0 + \underset{(9.92)}{.7642\ RPCU_{t-1}} - \underset{(8.6)}{6407.6\ (TPR/TCR)} - \underset{(4.0)}{DUM2}$$

$\bar{R}^2 = .889$ DW = 1.70

Real price, copper
US$/metric ton

Exogenous:

DUM1 = Dummy variable = 1 in 1954, 1959, and 1967;
= zero for all other years.
DUM2 = Dummy variable = 1 in 1960 and 1972;
= zero for all other years.
DUMRC = adjustment to consumption
DUMRP = adjustment to production

FATS AND OILS (P.Pollak):

A. Price Equations: (U.S. $ per metric ton)

$PSOY = 91.04 + 1.974\ PITOT - 0.019\ XSOY + 0.020\ Y63$	Soybean Oil
$PGNO = 393.48 + 1.597\ PITOT - 0.228\ XGNO + 0.01\ Y63$	Groundnut Oil
$PCOT = 170.43 + 2.306\ PITOT - 0.395\ XCOT + 0.05\ Y63$	Cottonseed Oil
$PSUN = 105.24 + 2.088\ PITOT - 0.056\ XSUN + 0.037\ Y63$	Sunflower Oil
$PRAP = 86.88 + 1.85\ PITOT - 0.073\ XRAP + 0.02\ Y63$	Rapeseed Oil
$PCOC = 450.48 + 1.623\ PITOT - 0.223\ XCOC + 0.0001\ Y63$	Coconut Oil
$PKER = 81.32 + 1.832\ PITOT - 0.027\ XKER + 0.0001\ Y63$	Palm Kernel Oil
$POLV = 335.58 + 4.975\ PITOT - 1.814\ XOLV + 0.0001\ Y63$	Olive Oil
$PLRD = 201.98 + 1.335\ PITOT - 0.212\ XLRD + 0.007\ Y63$	Lard
$PALM = 98.90 + 1.912\ PITOT - 0.083\ XALM + 0.011\ Y63$	Palm Oil
$PFSH = 1.87 + 1.651\ PITOT - 0.023\ XFSH + 0.014\ Y63$	Fish Oil
$PTAL = 138.21 + 1.831\ PITOT - 0.101\ XTAL + 0.007\ Y63$	Tallow

B. Export Equations: ('000 metric tons)

$XSOY = -492.96 + 0.5207\ QSOY$	Soybean Oil
$XGNO = 344.01 + 0.1046\ QGNO$	Groundnut Oil
$XCOT = -220.12 + 0.2208\ QCOT$	Cottonseed Oil
$XSUN = -708.11 + 0.3551\ QSUN$	Sunflower Oil
$XRAP = -273.63 + 0.4574\ QRAP$	Rapeseed Oil
$XCOC = 408.27 + 0.4191\ QCOC$	Coconut Oil
$XKER = 160.125 + 0.4082\ QKER$	Palm Kernel Oil
$XOLV = -32.32 + 0.1098\ QOLV$	Olive Oil
$XLRD = -23.17 + 0.1202\ QLRD$	Lard
$XALM = -163.14 + 0.6369\ QALM$	Palm Oil
$XFSH = -115.75 + 0.6975\ QFSH$	Fish Oil
$XTAL = -349.48 + 0.4373\ QTAL$	Tallow

$$PITOT = \frac{\sum_{i=1}^{12} POL_{it} \cdot W_{io}}{\sum_{i=1}^{12} POL_{io} \cdot W_{io}}$$

FAO Price Index,
all fats and oils

C. Exogenous Production Estimates:
('000 metric tons)

		Projected Growth Rate
QSOY	Soybeans	5.7
QGNO	Groundnut Oil	2.3
QCOT	Cottonseed Oil	.6
QSUN	Sunflower Oil	1.7
QRAP	Rapeseed Oil	3.3
QCOC	Coconut Oil	1.3
QKER	Palm Kernel Oil	.15
QOLV	Olive Oil	2.5
QLRD	Lard	1.1
QALM	Palm Oil	4.8
QFSH	Fish Oil	1.0
QTAL	Tallow	1.6

IRON ORE (F. Pinto):

$$SCTOT = -54225. + \underset{(27.2)}{287.78}\ Y63$$

$$\bar{\bar{R}}^2 = .978 \qquad DW = 1.97$$

Steel Consumption, total '000 metric tons raw steel equipment

$$PROD = \underset{(37.29)}{1.0901}\ SCTOT + \underset{(6.07)}{2601.2}\ RPRS$$

$$\bar{\bar{R}}^2 = .948 \qquad DW = 2.09$$

Iron Ore Production, world total '000 metric tons

$$RATIO3 = .7628 - \underset{(2.96)}{.00606}\ T$$

$$\bar{\bar{R}}^2 = .463 \qquad DW = .64$$

OECD share production of iron ore

$$PRODP = (1 - RATIO3)\ PROD$$

LDC production '000 m.t.

$$XLDC = .7288\ PRODP$$

LDC exports '000 m.t.

Exogenous:

RPRS - Real price of iron ore (in US$/metric ton)

RICE (N. Hicks):

$$RPRC = -47.484 + \underset{(5.37)}{.2334\ Y63} - \underset{(3.28)}{.04565\ QXRC} + \underset{(11.78)}{3.159\ RPWH} - \underset{(4.52)}{909.4\ GRIPI}$$

$$\bar{R}^2 = .939 \qquad DW = 2.45 \qquad 1961\text{-}74$$

Real price, rice
US$/metric ton

$$QPUS = 1106.9 + \underset{(3.57)}{4.5419\ RPRC_{t-1}} + \underset{(5.26)}{107.8\ T}$$

$$\bar{R}^2 = .783 \qquad DW = 1.20 \qquad 1962\text{-}74$$

U.S. Production (paddy)
'000 tons

$$XUS = -207.8 + .5028\ QPUS_{t-1}$$

U.S. Exports (milled basis)
'000 tons

$$QPCH = 56368.1 + \underset{(13.27)}{1961.7\ T} + \underset{(3.75)}{5598.8\ RL3}$$

$$\bar{R}^2 = .962 \qquad DW = 2.90 \qquad 1962\text{-}74$$

China, production (paddy)
'000 tons

$$RL3 = RPRC_{t-3}/RPWH_{t-3}$$

Relative price, rice:wheat

$$XCH = 1212.1 + \underset{(2.30)}{.01736\ QPCH} + \underset{(2.56)}{1.950\ RPRC}$$

$$\bar{R}^2 = .513 \qquad DW = 1.48 \qquad 1961\text{-}74$$

China, exports (milled basis)
'000 tons

$$XOTH = -5.244 + \underset{(3.29)}{69.13\ T} + \underset{(3.46)}{5.9846\ RPRC_{t-2}}$$

$$\bar{R}^2 = .606 \qquad DW = 2.99 \qquad 1961\text{-}74$$

Exports, other
'000 tons

$$XRC = XUS + XCH + XBU + XTH + XOTH$$

Exports, total

Exogenous:
T= time trend, 1955= 1
GRIPI= growth rate IPI
XBU= exports, Burma
XTH= exports, Thailand
RPWH= real price wheat (US$/metric ton)

RUBBER (J. Gunning/ E. Grilli):

$$\ln(C + CS) = -2.36 + \underset{(42.2)}{1.52} \ln Y63$$
$$\bar{R}^2 = .992 \qquad 1957\text{-}72$$

Total Consumption

$$C/(C + CS) = .23 + \underset{(13.6)}{470.7} (1/QS)$$
$$\bar{R}^2 = .939 \qquad 1960\text{-}72$$

Natural: Total Consumption

$$YMS = \underset{(14.8)}{.000083} RPR + \underset{(20.7)}{.016} T$$
$$\bar{R}^2 = .883 \qquad 1955\text{-}70$$

Yield, Malaysan small holders

$$YME = .17 + \underset{(3.0)}{.000025} RPR + \underset{(32.8)}{.018} T$$

Yield, Malaysian estates

$$QM = AMMS \cdot YMS + AMME \cdot YME$$

Malaysian Production

$$QO = 1180.2 + \underset{(8.1)}{37.75} T$$
$$\bar{R}^2 = .832 \qquad 1957\text{-}70$$

Other Production

$$Q = QO + QM$$

Total Production

$$RPR = 932.9 + \underset{(3.5)}{.66} RPR_{t-1} - \underset{(2.1)}{1.02} (Q+STD-C)$$
$$\bar{R}^2 = .730 \qquad 1959\text{-}1972$$

Real Price

Exogenous:

QS = synthetic rubber production, '000 metric tons.

STD = changes in government stockpiles (= 0 in projection period)

T = time trend, 1955=1.

Notation

C	-	Consumption of natural rubber (excl. Eastern Europe and China) in '000 metric tons.
CS	-	Consumption of synthetic rubber (excl. Eastern Europe and China).
YMS, YME	-	Yield Malaysian smallholders, estates, in metric tons/acre.
Q	-	World production, natural rubber, '000 metric tons.
STD	-	Deliveries from government stockpiles, '000 metric tons.

SUGAR (E.Brook/ P.Pollak):

$\log SP = -.9698 + \underset{(4.23)}{.3615} \log SP_{t-1} - \underset{(-7.36)}{.3783} \log XWR_{t-1} \underset{(2.55)}{-1.529} \log(1/IPF) + \underset{(2.98)}{2.2161} \log (1/IPF)_{t-1}$ $\bar{R}^2 = .87 \quad DW = 1.24$	Sugar price, 1972$ US¢/pound
$\log AHEU = .1237 + \underset{(23.67)}{.9513} \log AHEU_{t-1} + \underset{(3.34)}{.0994} \log SP_{t-1}$ $\bar{R}^2 = .96 \quad DW = 2.18$	Area Harvested, Eastern Europe '000 ha.
$\log AHUSC_t = -4825.4 + \underset{(3.74)}{104.1} PUS_{t-1} + \underset{(3.35)}{31.22} POPUS_t + \underset{(1.98)}{.3110} AHUSC_{t-1} - 91.31 T$ $\bar{R}^2 = .59 \quad DW = 1.97$	Area Harvested U.S. (Cane) '000 ha.
$AHUSB_t = -7270.3 + \underset{(2.37)}{.3573} AHUSB_{t-1} + \underset{(2.36)}{114.74} PUS_{t-1} + 46.12 POPUS - 110.4 T$ $\bar{R}^2 = .91 \quad DW = 2.26$	Area Harvested U.S. (Beet) '000 ha.
$AHUK = 12.345 + \underset{(1.31)}{2.162} SP_{t-1} + \underset{(6.74)}{.8632} AHUK_{t-1}$ $\bar{R}^2 = .74 \quad DW = 2.38$	Area Harvested, U.K. '000 ha.
$\log AHRWB = \log 3.1388 + \underset{(12.85)}{.01186} T$ $\bar{R}^2 = .90 \quad DW = 1.86$	Area Harvested rest of world (Beet) '000 ha.
$\log AHRWC = .3324 + \underset{(26.73)}{.9177} \log AHRWC_{t-1}$ $\bar{R}^2 = .97 \quad DW = 2.10$	Area Harvested rest of world, (Cane) '000 ha.
$CRW = CRW_{t-1} \cdot (1 + GRY63)$	Consumption, rest of world '000 tons
$EPEU = 3.0\ AHEU - CEU$	Excess production, Eastern Europe '000 tons
$EPCH = 3.8\ AHCH - CCH$	Excess production, China '000 tons
$EPCU = 5.1\ AHCU = CCU$	Excess production Cuba '000 tons
$EPRW = 3.45\ AHRWC + 5.2\ AHRWB - CRW$	Excess production , rest of world '000 tons
$ECUS = CUS - 2.3\ AHUSB_t - 3.45\ AHUSC$	Excess consumption, U.S. '000 tons
$ECUK = CUK - 5.8\ AHUK$	Excess production, U.K. '000 tons
$XWR = \dfrac{EPEU + EPCH + EPCU + EPRW}{ECUS + ECUK}$	Excess production-consumption ratio

Exogenous:

	Projected Growth rate
AHCH - area harvested China	4.0%
CEU - consumption, Eastern Europe	4.0%
CCH - consumption, China	6.5%
CCU - consumption, Cuba	1.7%
GRY63 - growth rate Y63	
T - Time trend, 1952 = 1	

Yield per ha. = 3.0 tons

TEA (N. Hicks):

$$RP = 403.3 - \underset{(2.29)}{40.426} \log QWP - \underset{(3.53)}{1.991}\,T + \underset{(4.59)}{14.338}\,D68$$

Real price, tea
US ¢/pound

$\bar{R}^2 = .972$ DW = 2.01 1955-72

$$QWP = \underset{(13.71)}{2.294}\,M + \underset{(1.93)}{1.295}\,RP_{t-4} - 502.8$$

World Production
('000 metric tons)

$\bar{R}^2 = .921$ DW = 2.46 1955-72

$$M = 673.7 + \underset{(2.52)}{.1160}\,Y63 - \underset{(2.77)}{1.6046}\,RP_{t-1}$$

World Imports
('000 metric tons)

$\bar{R}^2 = .937$ DW = 2.06 1955-72

Exogenous:
T = time trend, 1952 = 1.0

D68 = dummy variable, = zero after 1967, =1 before 1967

TIN (F. Pinto):

$$MP = \underset{(14.27)}{.8517}\,MP_{t-1} + \underset{(2.86)}{.0051}\,RP_{t-1}$$

Mine Production
'000 metric tons

$\bar{R}^2 = .92$ DW = 2.08 1961-73

SUPPLY = MP + DISP

Total Supply '000 m.t.

$$CT = 160.2 + \underset{(3.8)}{.582}\,CT_{t-1} + \underset{(3.7)}{.0118}\,RPT_{t-1} - \underset{(3.05)}{288.6}\,\frac{(RPA_{t-1})}{(RPT_{t-1})} + \underset{(2.37)}{.0235}\,Y63$$

Consumption '000 m.t.

$\bar{R}^2 = .94$ DW = 1.72 1954-73

$$RPT_t = 3250.2 + \underset{(5.3)}{.6828}\,RPT_{t-1} - \underset{(2.3)}{4907.8}\,(STK/CT)$$

Real price, tin
US\$/metric ton

$\bar{R}^2 = .766$ DW = 1.58 1954-73

$$STK = SUPPLY - CT + STK_{t-1}$$

Stocks

RPA - Real price aluminum, US$/metric ton (1974 = 100).

Editor's note: The GNP projections developed by the Workshop on Alternative Energy Strategies (WAES) with assistance from the World Bank were used in the Global 2000 Study (1) because the U.S. Government has no capability to make the disaggregated global economic projections needed for this Study, (2) because the World Bank/WAES GNP Projections were recommended by the World Bank staff, and (3) because there was no alternative. The computer printout for the World Bank/WAES GNP projections was destroyed long ago. Even the World Bank model with which the projections were made has been modified significantly and no copy of the original model retained. Chapters 3 and 16 of Volume 2 of the Global 2000 report provide as much information as could be obtained on the World Bank/WAES GNP projections. The only information on these projections that was published by the WAES Study team is on pages 217–221 of the *Third Technical Report of the Workshop on Alternative Energy Strategies,* Cambridge, Mass.: M.I.T. Press, 1977. These pages are reprinted here.

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Energy and Economic Growth Prospects for the Developing Countries

6.1 PREFACE

The Workshop on Alternative Energy Strategies has focused on projected energy supply and demand in the industrialized world. Members of WAES come from fifteen countries, most of them in the industrialized world outside of Communist areas (WOCA). We believe that the actions of these countries—or their failure to act—to alleviate possible future shortages of world energy will significantly affect the energy prospects of the developing nations.

In the WAES analyses, it is necessary to make assumptions about the energy supply and demand patterns in what is termed "Rest of WOCA"—WOCA countries outside Western Europe, North America, and Japan. These countries consist primarily of the developing countries (both OPEC and non-OPEC) but also include Australia, New Zealand, and the Republic of South Africa.

We have relied extensively on others with knowledge of these countries to help analyze their future energy supply and demand prospects. In particular, individuals from the International Bank for Reconstruction and Development (World Bank) have been most helpful in estimating developing country economic growth rates to 1990, deriving relevant income elasticities of energy demand, and providing energy supply estimates to 1980.

The energy supply estimates by fuel type for 1980 to 1985 come from World Bank and WAES sources, and the 1985 to 2000 figures are taken from the WAES global supply estimates for oil, gas, and coal.

The energy supply-demand estimates in this paper are very tentative. Historical data on energy consumption in developing countries are generally incomplete and are clouded by the fact that a significant proportion of total energy consumption comes from noncommercial sources such as firewood, cow dung, and vegetable waste. The survey also attempts to cover over ninety countries and so is exceedingly general in nature.

This report was prepared jointly by William F. Martin (WAES Staff) and Frank J.P. Pinto (Consultant to WAES and the World Bank). The authors gratefully acknowledge the written papers and verbal communications received from Nicholas Carter, John Foster, and William Humphrey of the World Bank and Alan Strout of the MIT Energy Laboratory.

This report attempts to answer the following questions, which are essential to the WAES global supply-demand analysis: (1) Given certain assumptions regarding economic growth, what is the probable range of commercial energy consumption in the developing countries during 1985 and 2000? (2) What potential domestic energy supplies are available to help these countries meet their anticipated demands? (3) What would be the probable range of desired imports (or exports) of energy by these countries? Possible answers to these questions represent the boundaries of the study. We recognize that the developing countries will need appropriate mechanisms to help them achieve desired levels of economic growth and that new arrangements may be needed to assist developing countries in meeting the rising costs of energy. Such arrangements must be part of a broad and complex system of existing economic relationships and institutions, an analysis of which is outside the scope of the WAES study.

6.2 INTRODUCTION

This paper focuses on the energy and economic growth prospects of the OPEC and non-OPEC developing economies in the world outside Communist areas (WOCA).[1]

6.2.1 Projected Shares of World Energy Consumption

Primary energy consumption in the developing countries during 1972 constituted approximately 15 percent of total WOCA energy consumption. As these countries industrialize, their share will rise relatively faster than that of the industrialized world. The WAES global supply-demand integrations suggest that the developing countries could consume as much as 25 percent of total world energy by the year 2000, as Figure 6.1 illustrates.

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[1] Estimates of energy supply and demand for Australia, New Zealand, and the Republic of South Africa are also included in the worksheets in section 6.6. Because these countries did not participate in WAES, it was necessary to make provisional estimates for them on the basis of published source material and information from individuals within the Workshop who were familiar with the energy prospects in these countries.

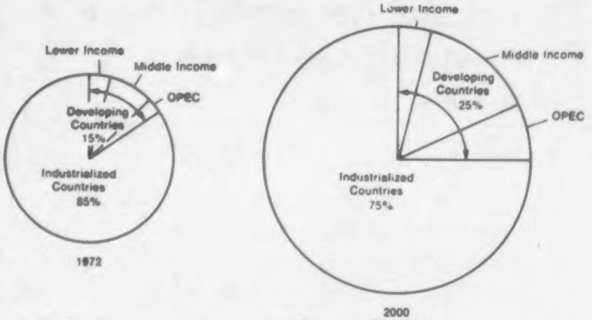

Figure 6.1
Shares of WOCA energy consumption.

6.2.2 Developing Country Coverage

The 93 developing nations in WOCA considered in this analysis are divided into two major groups: (1) the 13 OPEC countries and (2) the non-OPEC developing nations of Asia, Africa, and Latin America. The latter group is further divided into two classifications according to per capita income (the number of countries in each category is in parentheses):

- *Lower-income countries* comprising those developing economies with per capita annual income below $200. The countries in this group fall into two regions: South Asia (7) and lower-income sub-Sahara Africa (20).
- *Middle-income countries* comprising those developing economies with per capita annual income above $200. These countries can be grouped into three regions: East Asia (9); Caribbean, Central and South America (21); middle-income sub-Sahara Africa and West Asia (23). Per capita incomes range from $200 to around $1000 with the mean being about $550.[2]

These classifications are identical to those used by World Bank. A detailed list of the countries in each major group is given in Table 6.1.

6.2.3 Population Trends

An important factor in the analysis of energy consumption in the developing world is the present level and future growth rate of population. WOCA had a population of around 2.7 billion in 1975, and it is estimated that this figure will increase to 4.5 billion by the year 2000. The industrialized nations of North America, Europe, Japan, and Oceania constituted approximately 28 percent of the total population in 1975 and will probably constitute around 20 percent by the year 2000.

Table 6.2 presents estimates of the absolute levels and growth rates of population for the developed and developing nations for the years 1970, 1975, 1985, and 2000. Most of these figures have been derived from United Nations population projections. The energy problems facing the developing economies are more severe because of their 2.4–2.7 percent average population growth between now and 2000, as compared to 0.7–0.9 percent for the industrialized world.

6.2.4 WAES Scenario Assumptions

WAES uses the scenario approach in its studies to 1985 and 2000. The scenario variables include economic growth (high or low), real energy price (rising, constant, or falling), government policy (vigorous or restrained), and, for 1985 to 2000, principal replacement fuel (coal or nuclear). For the developing economies, only a constant real energy price to 1985 was examined. Furthermore, government policy response to 1985 is not included as a variable due to the uncertainty in modeling an aggregate policy response for over ninety countries. The WAES scenario cases considered in the analysis of developing country prospects are more fully specified in Table 6.3.

6.2.5 Methodology

The first step is the determination of economic growth rates for the developing nations, primarily from the World Bank's SIMLINK Model.[3] High and low economic growth rate assumptions for the developed economies, as well as the WAES oil price assumption of $11.50 (per barrel of light Arabian crude, FOB Persian Gulf, in constant 1975 U.S.$) are special inputs to the model, whose simulations then provide economic growth projections for the major developing regions of WOCA to 1985. Figure

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[2] These distinctions are based on data in the 1974 and 1975 *World Bank Atlas*. They relate to the year 1972.

[3] "The SIMLINK Model of Trade and Growth for the Developing World," World Bank Staff Working Paper No. 220, October 1975. Also in *European Economic Review*, Vol. 7 (1976), pp. 239–255. SIMLINK is primarily a medium-term forecasting system in which exports of the non-OPEC developing countries are related to the level of economic activity in the OECD countries through a series of individual commodity models. Growth in the developing countries is linked to investment levels and imports; imports in turn depend on export earnings and inflows of foreign capital. Given assumptions as to OECD growth, the availability of foreign capital to the developing countries, and the international price of petroleum, the model may be run to determine either the import-constrained GDP growth rates to be anticipated in developing countries or the real resource transfer they would need to support a specified GDP growth target.

Table 6.1
Classification of developing countries

OPEC Countries

- Algeria
- Ecuador
- Gabon
- Indonesia
- Iran
- Iraq
- Kuwait
- Libya
- Nigeria
- Qatar
- Saudi Arabia
- United Arab Emirates
- Venezuela

Non-OPEC Developing Countries

Lower-Income Countries [annual per capita income under $200 (1972 U.S. $)]

South Asia	Lower-Income Sub-Sahara Africa	
Afghanistan	Burundi	Niger
Bangladesh	Central African Republic	Rwanda
Burma	Chad	Sierra Leone
India	Dahomey	Somalia
Nepal	Ethiopia	Sudan
Pakistan	Guinea	Tanzania
Sri Lanka	Kenya	Togo
	Madagascar	Uganda
	Malawi	Upper Volta
	Mali	Zaire

Middle-Income Countries [annual per capita income over $200 (1972 U.S. $)]

East Asia	Middle-Income Sub-Sahara Africa and West Asia	Caribbean, Central and South America
Fiji	Angola	Argentina
Hong Kong	Bahrein	Barbados
Korea (South)	Cameroon	Bolivia
Malaysia	Congo P.R.	Brazil
Papua New Guinea	Cyprus	Chile
Philippines	Egypt	Colombia
Singapore	Ghana	Costa Rica
Taiwan	Israel	Dominican Republic
Thailand	Ivory Coast	El Salvador
	Jordan	Guatemala
	Lebanon	Guyana
	Liberia	Haiti
	Mauritania	Honduras
	Morocco	Jamaica
	Mozambique	Mexico
	Oman	Nicaragua
	Rhodesia	Panama
	Senegal	Paraguay
	Syria	Peru
	Tunisia	Trinidad and Tobago
	Turkey	Uruguay
	Yemen AR, DM	
	Zambia	

Table 6.2
Estimated developed and developing country population levels and growth rates, 1970–2000

	Population (in millions, rounded)				Population growth rate (%/yr)		
	1970	1975	1985	2000	1970–75	1975–85	1985–2000
Total population in WAES analysis	2399	2661	3310	4475	2.1	2.2	2.05
Developed economies	702	732	792	872	0.9	0.8	0.7
Developing economies	1697	1929	2518	3603	2.6	2.7	2.4
OPEC	255	292	388	566	2.8	2.9	2.6
Non-OPEC developing countries	1442	1637	2130	3037	2.6	2.7	2.4
Lower-income countries	889	1005	1301	1835	2.5	2.65	2.3
South Asia	740	835	1076	1487	2.4	2.6	2.2
Lower-income Africa	149	170	225	348	2.7	2.9	2.9
Middle-income countries	553	632	829	1202	2.7	2.75	2.5
East Asia	138	158	207	290	2.8	2.7	2.3
Middle-income Africa and West Africa	162	184	240	353	2.6	2.7	2.6
Caribbean, Central and South America	253	290	382	559	2.8	2.8	2.6

Table 6.3
WAES scenario assumptions

	Economic growth	Energy price[a]	Principal Replacement fuel
1976–1985			
C	High	$11.50	
D	Low	$11.50	
1985–2000			
C-1	High	$11.50–$17.25	Coal
C-2	High	$11.50–$17.25	Nuclear
D-7	Low	$11.50	Coal
D-8	Low	$11.50	Nuclear

[a] Price per barrel light Arabian crude FOB Persian Gulf in 1975 U.S. dollars.

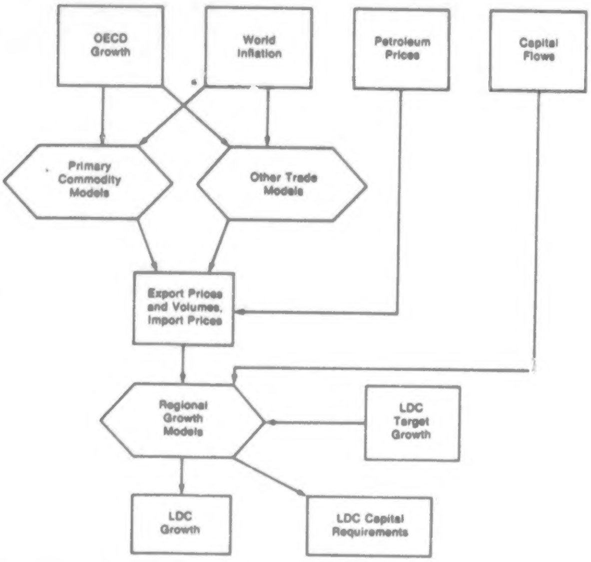

Figure 6.2
Flow diagram for SIMLINK III.

6.2 illustrates the SIMLINK flow from the exogenous input to the output.

The historical (1960 to 1972) relationship between regional economic growth and energy consumption is then examined by considering the income elasticity of demand for energy use. This is defined as the growth rate of energy consumption divided by the growth rate of real income. Since real energy prices rose substantially between 1972 and 1976 and are assumed to either remain constant (WAES Cases C and D in 1985, Cases D-7 and D-8 in 2000) or increase by 50 percent by year 2000 (WAES Cases C-1 and C-2), the historical income elasticities were revised downward for the period 1976 to 2000 to reflect the more energy-efficient use of resources in the future.

The primary energy demand growth rates are obtained from the real economic growth rates and the income elasticities of energy demand. The total primary energy consumption of developing countries in 1985 and 2000 can then be determined.

The energy supply estimates by fuel type for 1975 to 1985 come from World Bank[4] and WAES sources. The 1985 to 2000 estimates come primarily from the WAES global supply studies described in chapters 3 through 7 of the second WAES technical report.

Supply-demand integrations then balance available energy supplies with expected energy demands. The resulting figures show the range of energy exports and imports of both OPEC and non-OPEC developing countries.

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[4] A. Lambertini, "Energy and Petroleum in Non-OPEC Developing Countries, 1974–80," World Bank Staff Working Paper No. 229, February 1976.

6.3 DEMAND FOR ENERGY

6.3.1 Economic Growth Rate Assumptions, 1960–2000

The historical and projected economic growth rates for the developing economies for the period 1960 to 2000 are presented in Table 6.4. The 1976 to 1985 growth estimates have been derived primarily from simulation of the World Bank's SIMLINK Model using the WAES high (Case C) and low (Case D) economic growth assumptions for the OECD countries as well as the WAES constant oil price assumption of $11.50 per barrel (1975 U.S.$). Because SIMLINK is primarily a medium-term forecasting system, extrapolations were made to determine the 1985 to 2000 developing countries' economic growth rates.

Several of the middle-income countries profited by the commodity boom of 1972–1973 and should be able to achieve comparatively rapid growth over the next decade. Latin American and East Asian countries are expected to show the highest economic growth patterns among the non-OPEC developing countries due to higher capital productivity, an increase in the rate of investment, and export promotion. The lower-income countries will probably grow much slower than the middle-income countries, and they will continue to suffer from the effects of higher oil prices and agricultural shortfalls. The projected growth rates assume, however, that improvements will be achieved in domestic policies with special emphasis on increasing exports.

As a group, the non-OPEC developing countries are expected to maintain a growth rate higher than that of the OECD area. In the long run, middle-income countries are expected to grow 1–2 percent faster and low-income countries about 0.5 percent slower than the developed nations.

OPEC countries are expected to achieve high economic growth rates from 1976 to 1985, possibly as high as 7.2 percent per year in the high growth case and 5.5 percent per year in the low growth case. Several OPEC countries—mainly those with larger populations such as Algeria, Ecuador, Indonesia, Iran, Iraq, Nigeria, and Venezuela—are expected to have current-account deficits in their balance of payments by 1985. From 1985 to 2000 OPEC growth will likely decrease since many OPEC countries have undertaken large development projects that may cause foreign exchange shortages and curtailed imports after 1985.

6.3.2 Historical Growth in Energy Consumption, 1960–1972

From 1960 to 1972 the nations of the developing world more than doubled their consumption of commercial energy and increased their demand for electric power by more than 250 percent. In 1972 the developing countries accounted for around 15 percent of total world energy consumption in WOCA.

Sixteen countries accounted for about three-quarters of all developing world energy demand.[5] They are Argentina, Brazil, Chile, Colombia, Egypt, India, Indonesia, Iran, Korea, Mexico, Pakistan, Philippines, Taiwan, Thailand, Turkey, and Venezuela.

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[5] *Modern Power Prospects in Developing Countries*, Richard Barber Associates (1976).

Table 6.4
Real GNP growth rate assumptions, 1972–2000 (average annual percent growth)

Period	1960–1972	1972–1976	1976–1985		1985–2000	
Economic growth WAES case			High C	Low D	High C-1, C-2	Low D-7, D-8
Non-OPEC developing countries	5.6	5.1	6.1	4.1	4.6	3.6
Lower-income countries	3.7	2.3	4.4	2.8	3.1	2.5
Middle-income countries	6.2	5.9	6.6	4.5	4.9	3.9
OPEC	7.2	12.5[b]	7.2	5.5	6.5	4.3
Developed countries[a] (OECD)	4.9	2.0	4.9	3.1	3.7	2.5

[a] As derived by WAES analyses of individual countries.

[b] Preliminary estimate.

4 The Climate Sector

Introduction

The Global 2000 Study developed three climate scenarios for use as inputs to the various projection models.[*] These scenarios were patterned after scenarios developed in a recent climate study by the National Defense University (NDU), in cooperation with the National Oceanic and Atmospheric Administration, the Central Intelligence Agency, and the U.S. Department of Agriculture. The underlying methodology employed in developing the NDU scenarios is described in the NDU report,[1] and is excerpted here, including the NDU questionnaire. Most of this material, with the exception of the questionnaire, was included in Volume 2.

References

1. *Climate Change to the Year 2000: A Survey of Expert Opinion,* Washington: National Defense University, 1978, pp. 1-16, 59-77.

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[*] Unfortunately, after the climate scenarios were developed, it was discovered that none of the projection models used by the Government were designed to accept climate as an input variable, and as a result the Global 2000 climate scenarios could not be used.

Editor's note: This material is reprinted from *Climate Change to the Year 2000: A Survey of Expert Opinion,* Washington: National Defense University, 1978, pp. 1–16 and Appendix A, pp. 59–77.

METHODOLOGY

RESEARCH APPROACH FOR TASK I

General Features

The purpose of Task I was to define and estimate the likelihood of changes in climate during the next 25 years, and to construct climate scenarios for the year 2000. Information was collected from a carefully selected group of experts through the use of a structured questionnaire. Ten separate questions dealt with particular climatic variables and/or specific geographic regions of interest. These topics of inquiry were as follows:

- average global temperature
- average latitudinal temperature
- carbon dioxide and turbidity
- precipitation change
- precipitation variability
- mid-latitude drought
- outlook for 1977 crop year
- Asian monsoons
- Sahel drought
- length of the growing season

Each question elicited information about three elements: probabilistic (or equivalent) forecasts on a particular climatic variable, reasons for quantitative estimates, and self and peer expertise rating. The complete questionnaire is contained in Appendix A.

A panel of climatological experts from the United States and abroad was selected by the research team, with assistance from the project Advisory Group. The panelists were selected both for their competence in the field of climatology and for the diversity of views which they represented. The list of panelists responding to the questionnaire appears in the acknowledgments.

The questionnaires were sent to 28 panelists and 24 were returned. Of these, 21 contained quantitative information. Appendix C lists for each climate question the number of panelists who submitted quantitative estimates and the average of their expertise.

Panelists' Concerns

Most respondents, as well as some of the invited panelists who declined to participate, voiced some degree of apprehension or concern about the questionnaire and the use (and possible abuse) of the information derived from their responses. These concerns centered on the following issues:

- the lack of sufficient actuarial experience, comprehensive theories, or adequate models to support the quantitative estimates given in the questions,
- the possible suppression of the full range of uncertainty accompanying responses,
- the risk of being an unwitting party to "science by consensus."

The following comments by panelists reflect these concerns:

> To the best of my knowledge, there exist, in general, no techniques for making climate forecasts that have demonstrated skill in the sense that the forecasts are better than a forecast of the long-term average statistics. Knowledge of even the long-term average statistics (means, variances, extremes, conditional probabilities, etc.) would be most useful for some purposes, but even this data is not readily available.
>
> I think that the strongest message to come from your questionnaire will be that we lack the basis for predicting even the grossest aspects of climate.
>
> We possess no skill for forecasting beyond a short period, other than that which probabilities based on a frequency distribution can provide. Only a deterioration of climate will fire the imagination of the experts. Prophets become known for their prophecies of doom. A prophecy of status quo or improvement would not be interesting.
>
> There is a good deal of guesswork involved, due to uncertainties about feedback mechanisms, the importance of aerosols, the general circulation in the atmosphere and oceans, and many other factors.
>
> I feel that one of the most important outcomes of your study could be a clear statement of our present ignorance. That in itself should clearly indicate the need for contingency plans.

In the preparation of this report, the project team has given considerable attention to the foregoing concerns in analyzing the data and aggregating the range of views—and the expressed qualifications—provided by the respondents. Realizing that confident predictions of climate are beyond the state of the art, the project team has proceeded on the assumption that expert probabilistic judgments, properly qualified, constitute the best available guidance for those who must make policy in matters affected by climate. The climate data in the report bespeak uncertainty and a wide range of perceptions. In the description of the methodology and the presentation of the analysis and results, appropriate caveats have been introduced to avoid misunderstanding.

ANALYSIS OF DATA

Self and Peer Ratings

An interesting and useful feature of the questionnaire was the concept of self and peer ratings. Figure I-1 is an excerpt of the instructions provided at the end of each question and designed to assess the respondents' expertise.

Figure I-1

SELF AND PEER RATING

Using the self-ranking definitions provided in the instructions, please indicate your level of substantive expertise on this major question.

5 - 4 - 3 - 2 - 1

Again using the self-ranking guide, please identify those other respondents whom you would rate as "expert (5)" or "quite familiar (4)" in their answer to this particular question.

The categories from 5 to 1 (expert, quite familiar, familiar, casually acquainted, and unfamiliar) were carefully defined in the questionnaire. Table I-1 shows a sample of the degree of correlation between self and peer ratings for five respondents on Question I. The general agreement between self and peer ratings is fairly evident by a scan of the two right-hand columns in the table. A detailed analysis of the correlation between self ratings and the mean of peer ratings shows it to have a value of 0.52 at a significance level of 0.007. This is considered a fairly high correlation.

A simple averaging of self and peer ratings for each respondent on each question, rounded to the nearest integer value, provided a weighting that was subsequently used in aggregating responses. The particular weighting scale that was used is shown in Table I-2. Levels of expertise falling below "familiar" ("casually acquainted" and "unfamiliar") were not used in the processing. Of the three levels shown in Table I-2, the "expert" category was

Table I-1

CORRELATION BETWEEN SELF AND PEER RATINGS

(Examples from Question I)

Respondent	Self Rating	Frequency of Peer Ratings Expert	Quite Familiar
A	Expert	10	3
B	Expert	4	3
C	Quite familiar	-	3
D	Quite familiar	1	2
E	Familiar	-	-

weighted twice as heavily as the "quite familiar" category and the "quite familiar" was weighted twice as heavily as "familiar." In effect, this reflects the largely empirical and intuitive notion that an expert's opinion is worth about twice as much as one who is "quite familiar," which in turn is worth twice as much as an individual who is ranked as "familiar" with a topic.

Table I-2

CONVERSION OF EXPERTISE RANKING TO WEIGHTED SCALE

Expertise	Weight
Expert	4
Quite familiar	2
Familiar	1

Processing of Responses

The general schema for processing the information from the questionnaires was as follows:

- tabulate each respondent's probability density function with respect to change about a particular variable at a given time, or derive the probability density function from graphical information provided by the respondent.

- multiply each probability density function by the appropriate expertise weight (as described earlier).

- add the weighted density functions of respondents.

- divide the weighted and aggregated density functions by the sum of expertise weights to normalize the group response.

- combine the panel's responses on each climatic variable into a set of scenarios spanning the range of uncertainty or range of conditions described by the respondents.

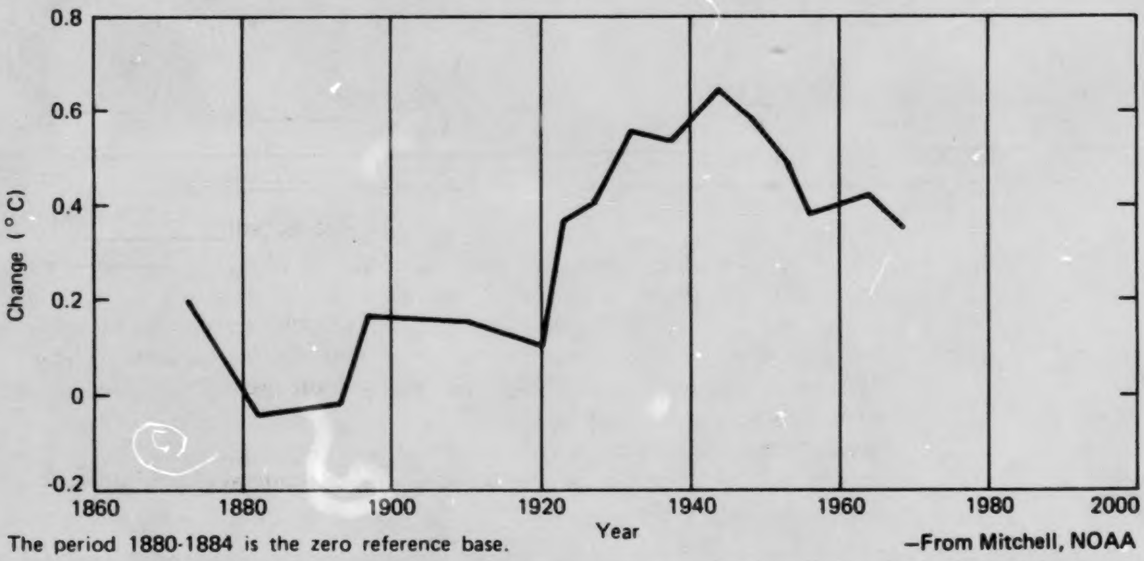
Question I, dealing with possible changes in global mean temperature*, was a pivotal question because perceptions of global mean temperature greatly influence perceptions with respect to the climate variables treated in subsequent questions.

Question I is based on Figure I-2, a plot of historical changes in annual mean temperature during the past century. Each respondent was asked to provide three estimates of the future course of possible changes in global temperature to the year 2000. The first estimate was to be a temperature path to the year 2000 such that there was only 1 chance in 10 that the actual path could be even lower. The second estimate was to be a path with an even chance that temperature could be either lower or higher; and the third was a path based on 1 chance in 10 that it could be even higher.

Figure I-2

GLOBAL TEMPERATURES

Historical record of changes in annual mean temperature during the past century for the latitude band, 0-80°N.



The period 1880-1884 is the zero reference base.

—From Mitchell, NOAA

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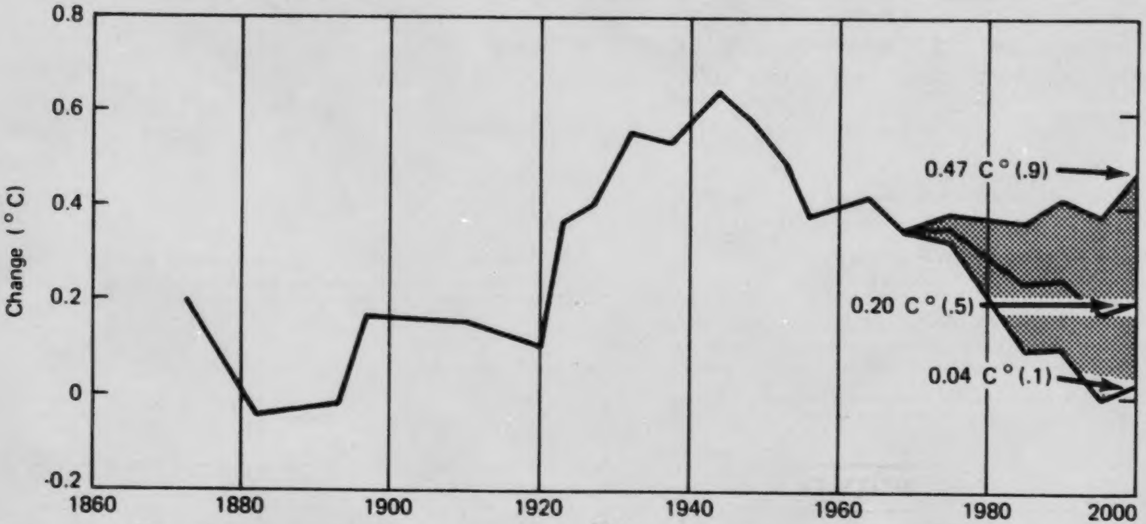
*For the purpose of this study, "global temperature" is used as equivalent to annual mean temperature between 0° and 80° north latitude.

Figure I-3 shows a sample response to Question I by a single respondent. Each of the three estimates could be drawn in any functional form desired. Percentiles of 10, 50, or 90 can be read off for any year between the "present" (the end of the plot in Figure I-2) and the year 2000.

Figure I-3

SAMPLE RESPONSE TO QUESTION I

Actual example of a single response to the instructions



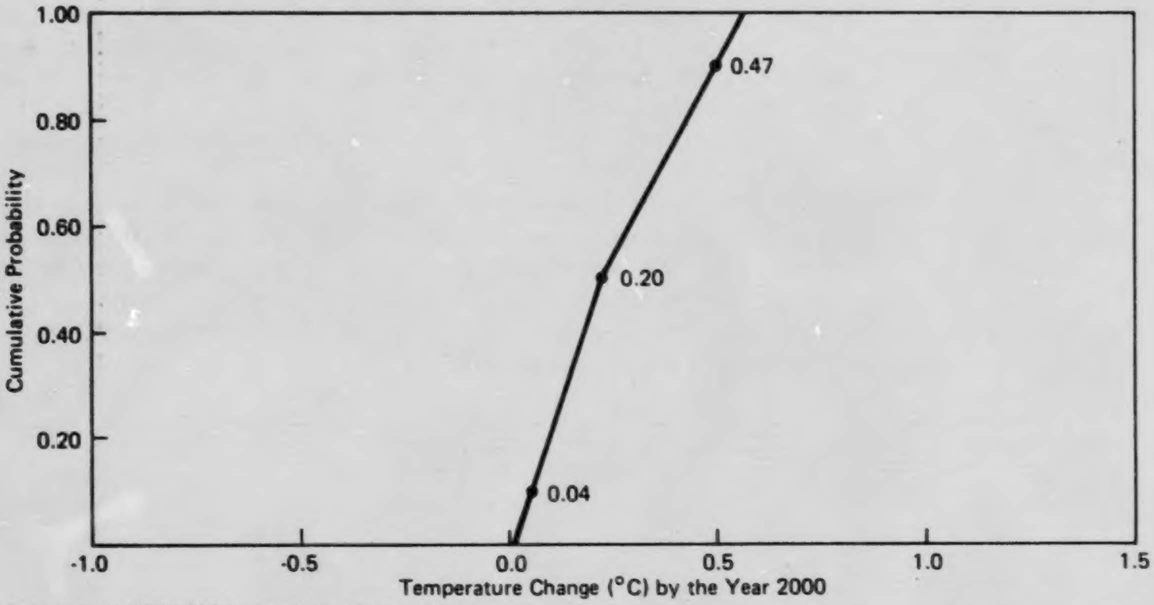
The period 1880-1884 is the zero reference base.

The processing of responses will now be illustrated using the answers to this question by a single respondent. Figure I-4 is a plot of the information shown in Figure I-3 for the year 2000, converted to a cumulative probability function in which the ends of the function have been extended beyond the 90th percentile and below the 10th percentile in a linear approximation. For example, the respondent has indicated a 10 percent chance that the temperature will change by 0.04°C or less, a 50 percent chance that it will change by 0.2°C or less, and a 90 percent chance that it will change by 0.47°C or less.** Similar values can, of course, be obtained for any other year from Figure I-3.

**These temperature changes are in relation to the zero reference base period, 1880-1884, as shown in Figure I-2.

Figure I-4

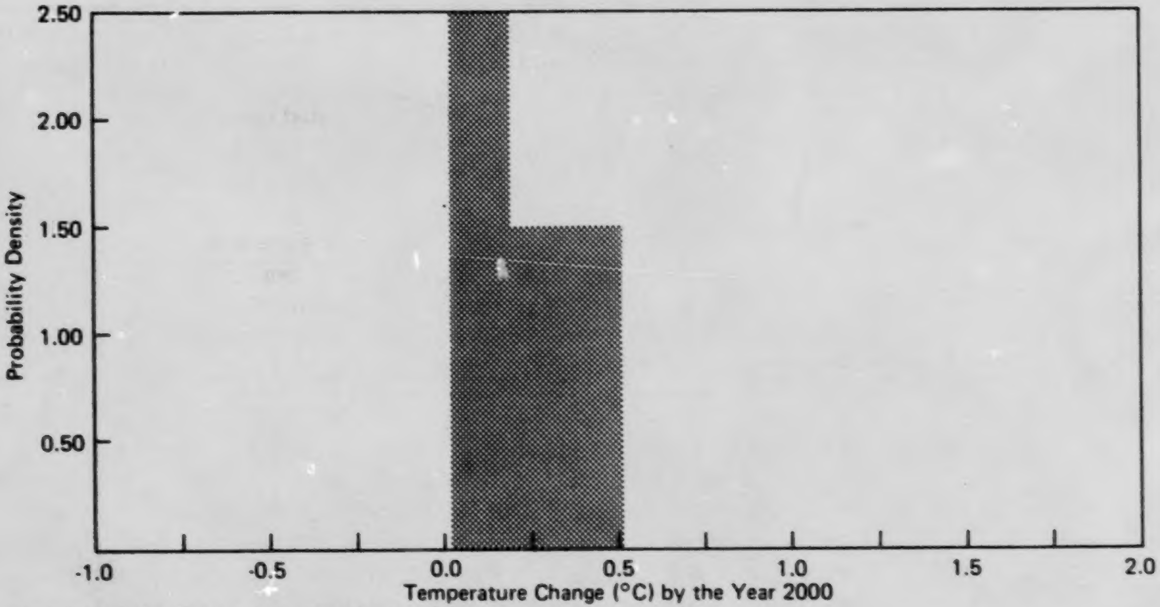
CUMULATIVE PROBABILITY FUNCTION FOR QUESTION I



The period 1880-1884 is the zero reference base.

Figure I-5

EQUIVALENT DENSITY FUNCTION FOR QUESTION I



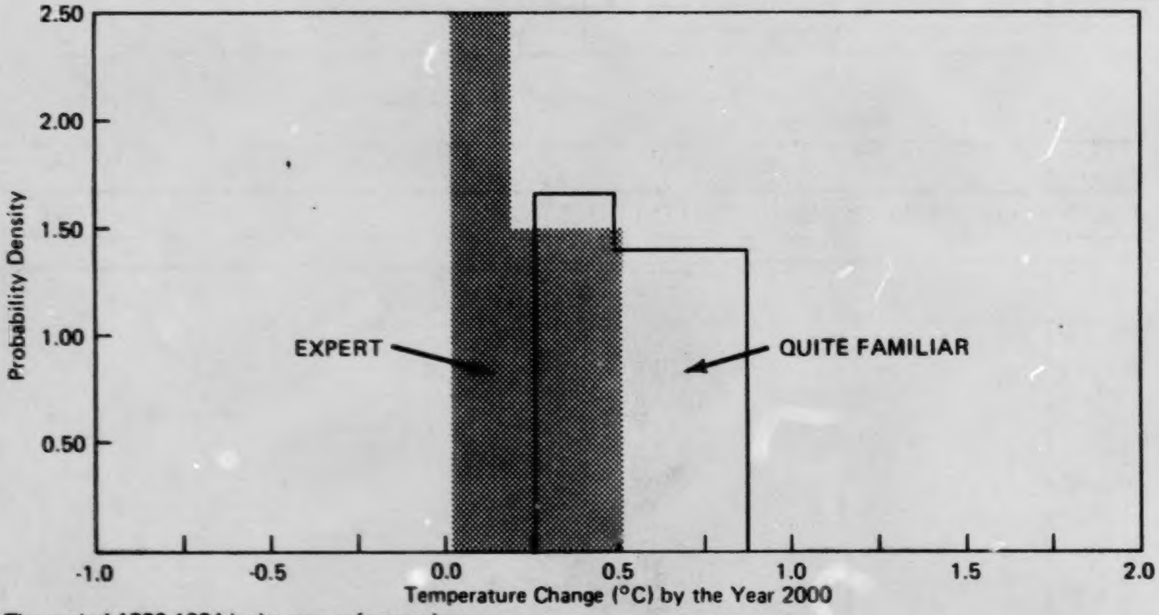
The period 1880-1884 is the zero reference base.

The next step is to convert the cumulative probability function into an equivalent density function by taking the first derivative of the plot in Figure I-4. Since the plot consists of two straightline segments, we have basically two degrees of freedom, or two levels in the density function, which is shown in Figure I-5. The area under the curve intercepted by any particular temperature range is equal to the probability of occurrence of that particular temperature range, and the total area under the curve in Figure I-5 is unity.

Figure I-6 shows unweighted density functions from each of two respondents. The two functions are next weighted by the appropriate expertise weights, added and then divided by the sum of the weights to obtain the combined and normalized density function for the two respondents. Again the area under the curve of this combined and normalized density function, shown in Figure I-7, is equal to unity.

Figure I-6

ADDING TWO DENSITY FUNCTIONS FOR QUESTION I

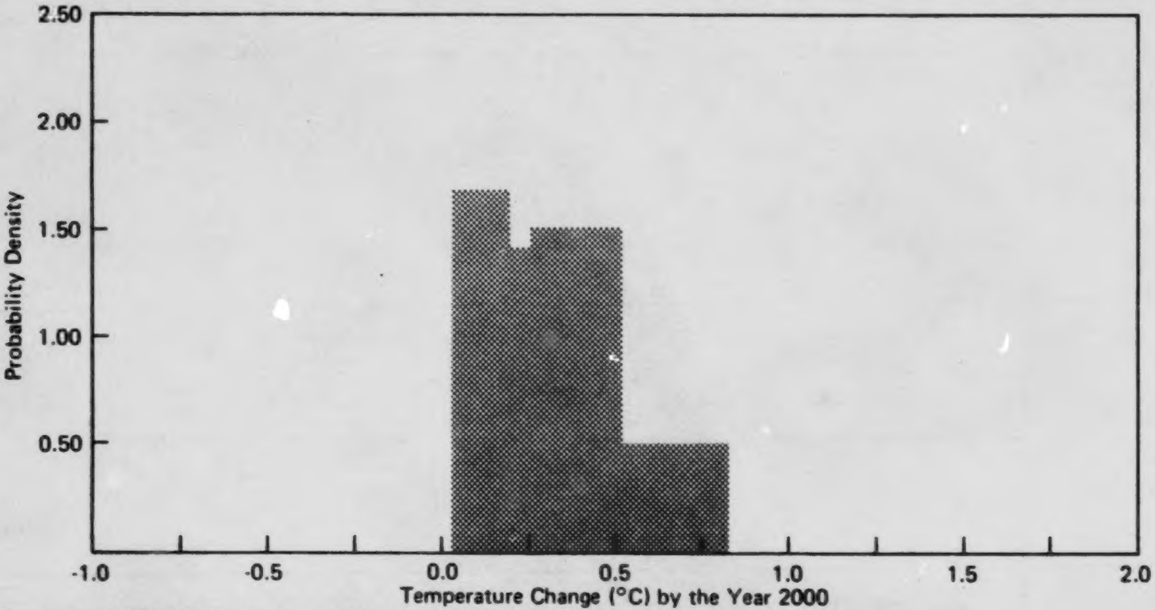


The period 1880-1884 is the zero reference base.

The procedure outlined above is repeated for the responses of each of the other panelists. Figure I-8 is a plot of the aggregated normalized responses of the full panel for the year 2000. An analogous procedure yields probability density functions of mean global temperature change for the years 1975, 1980, and 1990. The information contained in the probability density functions is shown in Figure I-9 as extensions to Mitchell's original curve. The extensions on the curve show the 10th, 50th and 90th percentiles for each year from the "present" to the year 2000. Intermediate percentiles are also plotted. Thus, Figure I-9 is a summary of the aggregated responses of the panelists with respect to global temperature.

Figure I-7

NORMALIZED DENSITY FUNCTION FOR TWO RESPONDENTS TO QUESTION I

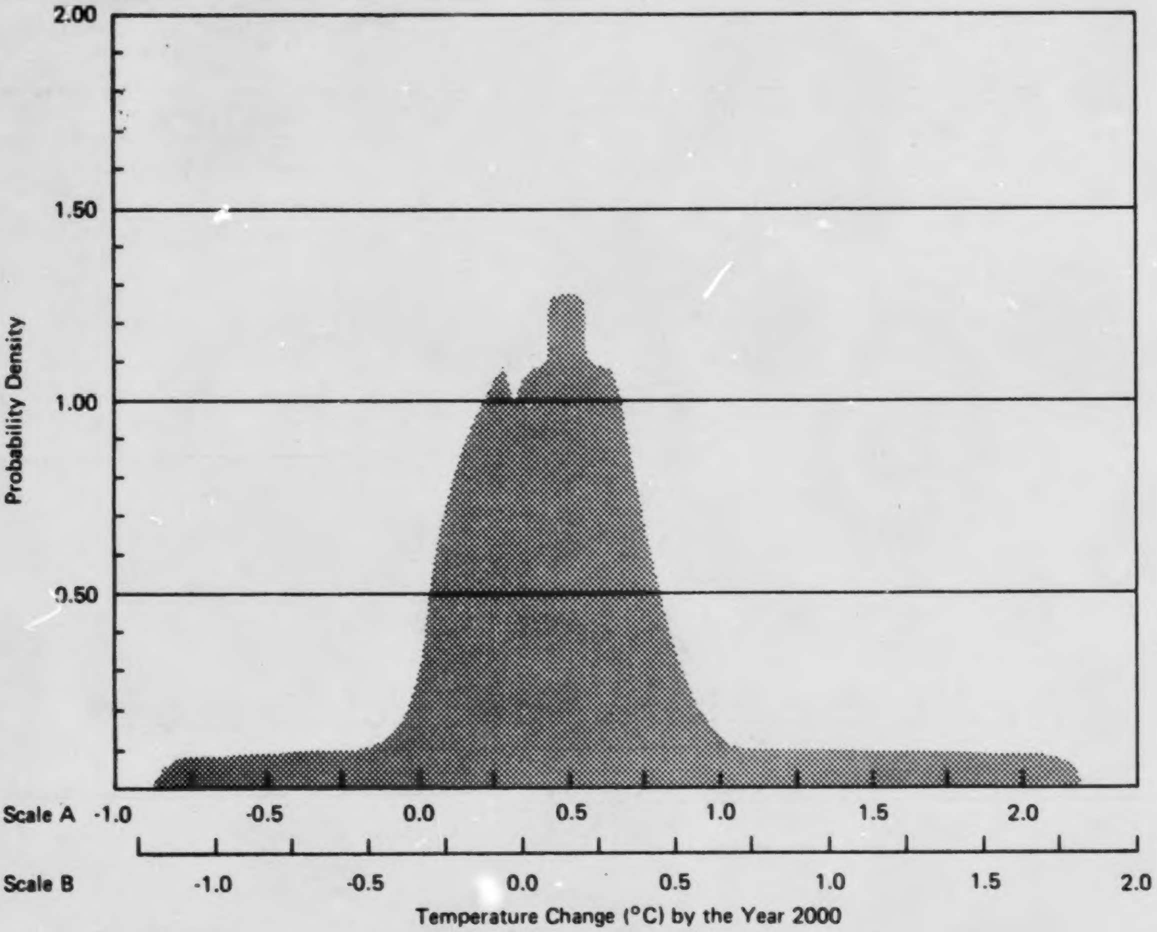


The period 1880-1884 is the zero reference base.

In aggregating the responses by the method of weighted averages, it has been assumed that the respondents are drawing from the same general information base and, therefore, that their information is highly dependent. In such cases of information dependence among respondents, it is customary to use the method of weighted averages to aggregate responses. All responses are used and weighted by the respondents' expertise as perceived by themselves and their peers. The shape and range of the aggregated curves are not acutely sensitive to the weighting system used. The method is "conservative" in the sense that the derived probability curves tend to be broad and to overstate uncertainty as a result of the additive treatment of the individual subjective probabilities. Had the responses been based on independent information, a multiplicative treatment of the individual probabilities would have been more appropriate, and the derived probability curves would have shown less dispersion.

Figure I-8

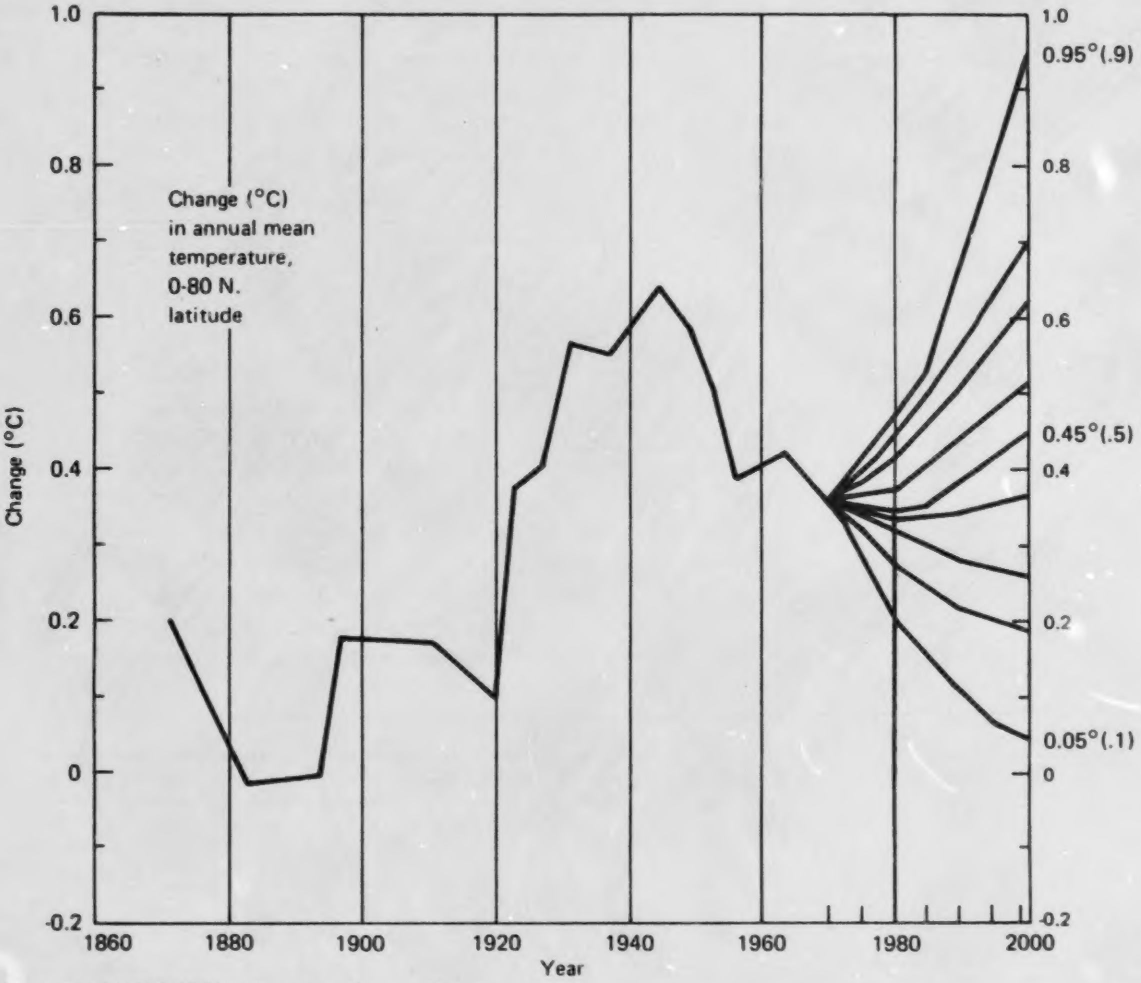
PROBABILITY OF MEAN NORTHERN HEMISPHERE TEMPERATURE CHANGE BY THE YEAR 2000 AS DETERMINED BY THE PANEL OF CLIMATIC EXPERTS



Scale A is based on the period 1880-1884 as the zero reference base (see Figure I-2).
Scale B is based on the period 1965-1969 as the zero reference base (see the end point on Figure I-2).

Figure I-9

PROBABILITY OF MEAN NORTHERN HEMISPHERE TEMPERATURE CHANGE TO THE YEAR 2000 AS DETERMINED BY THE PANEL OF CLIMATIC EXPERTS



The period 1880-1884 is the zero reference base.

CLIMATE SCENARIOS

Use of Scenarios

A convenient procedure for dealing with a range of uncertainty when it is not possible to construct quantitative models is through the use of scenarios, which may be considered plausible sequences of events or trends. Scenarios describe interconnections—perhaps even causal processes—and highlight, where possible, decision points. In a sense, a scenario is a possible "slice of future history."

Constructing Scenarios

In the present instance, since responses on global temperature are pivotal in setting the stage for other climate variables, the plot in Figure I-8 can be used as a basis for dividing the perceived temperature range into a number of categories. These categories then become the bases for constructing scenarios. The number of categories (and scenarios) is, in a sense, arbitrary and can be three or five or even a larger number, if desirable. Table I-3 shows the perceived temperature range divided into five categories. They range from large global cooling to large global warming. Associated with each temperature range is a probability of occurrence where, in fact, the temperature ranges were selected to make these probability ranges symmetrical.

Table I-3

DEFINITION OF TEMPERATURE CATEGORIES

Temperature Category	Change in Mean Northern Hemisphere Temperature from Present* by the Year 2000	Probability
Large cooling	0.3°C to 1.2°C colder	0.10
Moderate cooling	0.05°C to 0.3°C colder	0.25
Same as last 30 years	0.05°C colder to 0.25°C warmer	0.30
Moderate warming	0.25°C to 0.6°C warmer	0.25
Large warming	0.6°C to 1.8°C warmer	0.10

*"Present" temperature is defined as the end point on Mitchell's graph (Figure I-2) -- i.e., the average temperature for the five year period ending in 1969.

In order to process information with respect to other climate variables, it is useful to group respondents with respect to these five temperature ranges, according to where the bulk of each respondent's probability density function lies. Table I-4 is a matrix showing each of the five temperature categories arrayed as rows and the 19 respondents in 5 groups arrayed as columns of the matrix. As will be noted in Table I-4, the bulk of each group's probability density functions lies along the diagonal element of the 5x5 matrix (one respondent at each end, three and four at the intermediate ranges, and ten in the middle range).

The results of the information collected under Task I have been embodied in a set of five scenarios described in Chapter II, with more detailed discussion and comparisons in Chapter III.*

The scenarios are labeled in accordance with the global temperature categories in Table I-3. One purpose is to provide an integrated summary of perceptions of climatologists on climate change and variability to the year 2000. An equally important purpose is to provide a point of departure for structuring questions in Task II and to trace the impact of such possible climatic changes on food production and on the choice of policy options.

Table I-4

PERCENTAGE OF GROUPED PROBABILITY DENSITIES LYING IN EACH TEMPERATURE CATEGORY

Temperature Categories	Number of Respondents 1	3	10	4	1
Large cooling	99	12	2	--	--
Moderate cooling	1	68	24	10	--
Same as last 30 years	--	20	52	31	--
Moderate warming	--	--	22	44	20
Large warming	--	--	--	15	80

The procedure for creating scenarios corresponding to the five global temperature categories is as follows:

- Each respondent is first assigned to a global temperature category, as described in Table I-4.
- Responses within each temperature category are combined for all other climatic variables (except for precipitation and precipitation variability, where all responses were available**).
- Responses are integrated into a narrative, supported by summary tables.

---

*The responses to Question VII, "Outlook for 1977 Crop Year," are not included in the scenarios. That portion of the information for which expertise levels were considered adequate has been processed and is shown in Appendix B. Included is an analysis of subjective probabilities concerning the persistence of droughts in the U.S.

**For questions on precipitation and precipitation variability only, information was elicited from each respondent based on conditional assumptions with respect to global temperature.

The processing steps for Questions II through X are identical to those for Question I except that, of course, in these other instances, density functions or equivalents are provided directly by the respondents and need not be derived through the use of cumulative probability.

Figure I-10

QUESTION VI – MID-LATITUDE DROUGHT Frequency of Drought

Time period	"Frequent"-i.e., similar to early to mid-1930's and early to mid-1950's		"Average"-i.e., similar to the frequency over the longest period of record available		"Infrequent"-i.e., similar to 1940's and 1960's		Total Probability	
	US	Other mid-latitudes	US	Other mid-latitudes	US	Other mid-latitudes	US	Other mid-latitudes
1977 to 1980							1.0	1.0
1981 to 1990							1.0	1.0
1991 to 2000							1.0	1.0

The sequence of steps is illustrated by using Question VI, which concerns mid-latitude drought. Figure I-10 is an excerpt from Question VI. Table I-5 illustrates how responses for one of the time periods (i.e., 1991 to the year 2000) were weighted and aggregated in the Moderate Warming scenario. The process outlined for Question VI is repeated for each of the other questions.

Table I-5

FREQUENCY OF DROUGHT IN U.S. IN 1991-2000

Respondents Assigned to Moderate Warming	Expertise	Frequent	Average	Infrequent
A	3	0.25	0.50	0.25
B	3	0.60	0.20	0.20
C	5	0.60	0.20	0.20
Weighted average		0.54	0.25	0.21

Review of Scenarios

In June 1977, the project Advisory Group recommended that an *ad hoc* panel review early drafts of the five scenarios for internal and mutual consistency. Accordingly, project staff met in July with six climatologists at the National Center for Atmospheric Research at Boulder, Colorado. The reviewers paid particular attention to the large and moderate warming and cooling scenarios, i.e., those constructed from the smaller data bases. The details and the conditional probabilities of these end scenarios, therefore, reflect the judgments of more people than the limited number of panelists who responded to the questionnaires along the lines of these scenarios. The review process, which essentially strengthened the data bases of the end scenarios, resulted in significant changes to only one of them, the large global cooling scenario.

Nature of Scenarios

Each scenario seeks to describe average climatic conditions as they might exist in a period of years around A.D. 2000. The conditions do not refer specifically to the year A.D. 2000; the climate of that year is likely to differ from the scenario projection to an extent consistent with normal year-to-year climate variability. Some indication of the course of climate changes between the present time and the end of the century is also given in the narrative, and in the tables appended to each scenario.

Each scenario is assigned a "probability of scenario." This "probability" is a derived value based on the panelists' probabilistic temperature forecasts and a weighting scheme to take into account each respondent's expertise as rated by himself and his peers. Therefore, it reflects the range of judgments expressed by the climate panel and the strengths of their beliefs, as well as their level of expertise.*

This probability should not be construed as the likelihood that the *total* scenario will actually materialize in the future. The correct interpretation of the "probability of scenario" involves the following considerations:

---

*A "probability" of 0.25, for example, does not mean that there was universal agreement that the scenario in question would occur with probability 0.25. Nor does it mean that 25% of the panelists "voted" for that particular temperature change to the exclusion of other changes. Roughly speaking, the "probability" 0.25 is an amalgam of the proportion of panelists who gave some credence to that particular temperature change, the strength of their individual "beliefs" in the change (their individual probabilities of occurrence) and their individual expertise.

(1) The "probability" is essentially a measure of the confidence, expressed collectively by the climate panel, that *the global temperature change between circa 1970 and circa A.D. 2000 will lie in the range indicated by the scenario.* This measure of confidence bears an unknown relationship to the probability that the scenario will actually occur.

(2) It was assumed that the global temperature change indicated by the scenarios has a negligible probability of being greater than +1.8°C (the upper limit of Large Warming) or less than −1.2°C (the lower limit of Large Cooling). In this respect, the five scenarios, taken together, are considered to bracket all realistic outcomes--i.e., the probabilities of the five scenarios sum to unity.

(3) Details are given in each scenario which elaborate on the scenario in respects other than stipulated global temperature change. These are considered by the climate panel to be reasonable inferences about future climatic developments that are consistent with the global temperature change. These details by no means exclude other possible developments. Hence, they are not necessarily to be construed, individually or in combination, as having a probability as high as that indicated for the scenario as a whole. Conditional probability information, given in the tables included with each scenario, can be combined with the overall probability of the scenario to assess the absolute level of confidence to be placed in future events specified in the scenarios. For example, one can find the overall "probability" of a specified event (e.g., "frequent" drought in the U.S. for the period 1991-2000) by first calculating for each scenario the product of the "probability" of the scenario and the conditional probability of the event for that scenario, and then summing the products for all five scenarios.

APPENDIX A
CLIMATE QUESTIONNAIRE

INSTRUCTIONS FOR QUESTIONS

A. Attached is a set of 10 major questions, some of which have several parts. The timespan for the questions varies from the relatively near term (the outlook for the 1977 crop season) to the climate by the end of this century. All individual answers will be held in strict confidence. The aggregation and quantitative analysis of the responses will be made available to all participants and will be included in the final report.

We would appreciate your answering all of the questions in their present form. Your subjective responses may be used to generate another set of questions and to build a set of future climate scenarios. If, in reviewing and answering these questions, you feel strongly that a particular question should be rephrased or additional questions included, you are invited to add your comments or additional questions on extra pages.

B. In questions referring to latitudinal belts, the following definitions apply:

POLAR latitudes	65° to 90°
MIDDLE latitudes	30° to 65°
–Higher middle	45° to 65°
– Lower middle	30° to 45°
SUBTROPICAL latitudes	10° to 30°

C. For each of the 10 major questions, using the self-rating definitions provided below, please indicate your level of substantive expertise.

D. Please identify those other respondents whom you would rank as EXPERT (5) or QUITE FAMILIAR (4) in responding to each of the questions.

E. Guidance for self-ranking expertise:

(5) EXPERT—You should consider yourself an *expert* if you belong to that small community of people who currently study, work on, and dedicate themselves to the subject matter. Typically, you know who else works in this area; you know the US and probably the foreign literature; you attend conferences and seminars on the subject, sometimes reading a paper and sometimes chairing the sessions; you are most likely to have written up and/or published the results of your work. If the National Science Foundation, National Academy of Sciences, or a similar organization were to convene a seminar on this subject, you would expect to be invited, or, in your opinion, you should be invited. Other experts in this field may disagree with your views but invariably respect your judgment; comments such as "this is an excellent person on this subject" would be typical when inquiring about you.

CLIMATE QUESTIONNAIRE

INSTRUCTIONS FOR QUESTIONS (Continued)

(4) QUITE FAMILIAR—You are *quite familiar* with the subject matter either if you were an expert some time ago but feel somewhat rusty now because other assignments have intervened (even though, because of the previous interest, you have kept reasonably abreast of current developments in the field); or if you are in the process of becoming an expert but still have some way to go to achieve mastery of the subject; or if your concern is with integrating detailed developments in the area, thus trading breadth of understanding for depth of specialization.

(3) FAMILIAR—You are *familiar* with the subject matter if you know most of the arguments advanced for and against some of the controversial issues surrounding this subject, have read a substantial amount about it, and have formed some opinion about it. However, if someone tried to pin you down and have you explain the subject in more depth, you would soon have to admit that your knowledge is inadequate to do so.

(2) CASUALLY ACQUAINTED—You are *casually acquainted* with the subject matter if you at least know what the issue is about, have read something on the subject, and/or have heard a debate about it on either a major TV or radio network or an educational channel.

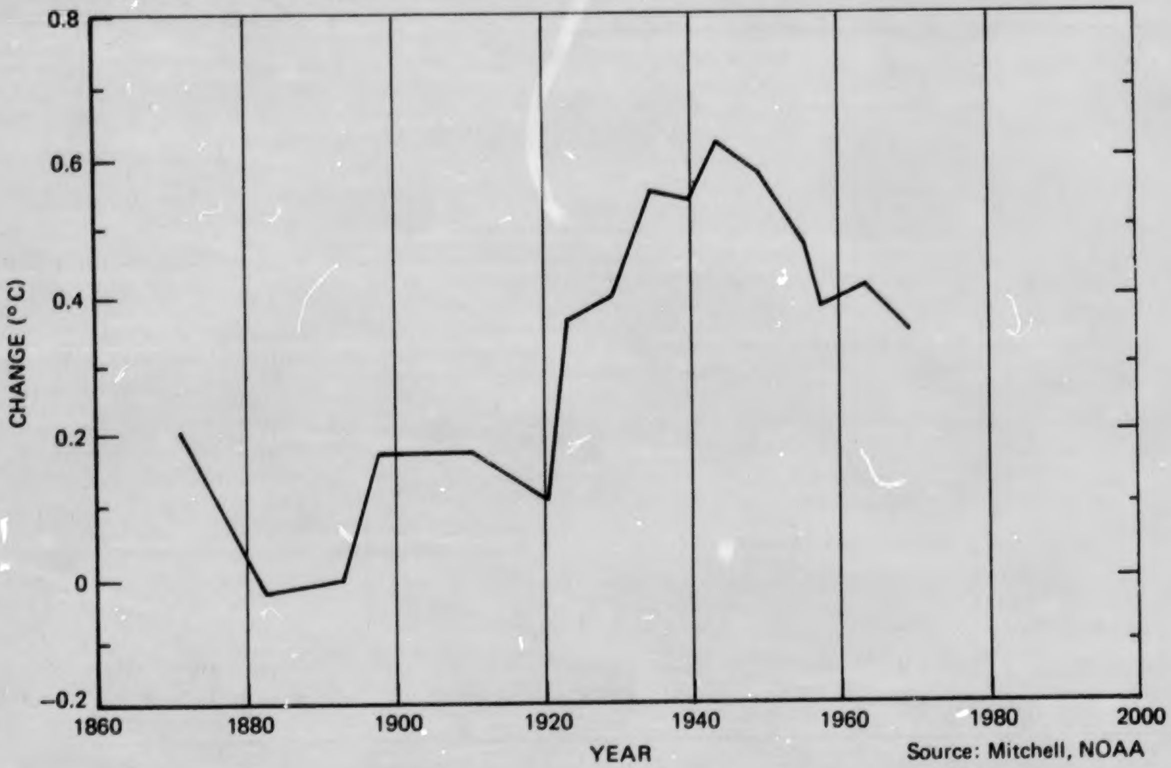
(1) UNFAMILIAR—You are *unfamiliar* with the subject matter if the mention of it encounters a veritable blank in your memory or if you have heard of the subject, yet are unable to say anything meaningful about it.

6

I. GLOBAL TEMPERATURES

Shown below is a historical record of changes in the annual mean temperature during the past century for the latitude band, 0-80°N.

CHANGE (°C) IN ANNUAL MEAN TEMPERATURE, 0-80 °N. LATITUDE



Source: Mitchell, NOAA

On the graph shown above, indicate your estimate of the general future course of the change in mean annual temperature (for 0-80° N.Lat.) to the year 2000 by:

- drawing a temperature change path to the year 2000 so that you estimate only 1 chance in 10 that the path could be even lower
- drawing a change path to the year 2000 so that you estimate an even chance that the path could be either lower or higher
- drawing a change path to the year 2000 so that you estimate 1 chance in 10 that the path could be higher

I. GLOBAL TEMPERATURES

In the space below, state your line of reasoning for the family of lines you have drawn, referencing if you wish, articles you or other scientists have written that clearly state your position on this subject.

- Using the self-ranking definitions provided in the instructions, please indicate your level of substantive expertise on this major question.

5–4–3–2–1

- Again using the self-ranking guide, please identify those other respondents whom you would rate as "expert (5)" or "quite familiar (4)" in their answer to this particular question.

EXPERT (5) QUITE FAMILIAR (4)

II. TEMPERATURE

Please fill in each block of the matrix below with your estimate of the probability of the change (°C) in the annual temperature by the year 2000, as compared with 1970-75, for the regions shown.

PROBABILITY OF TEMPERATURE CHANGE (°C)

	Cooling		"No Change"		Warming		Total Probability
	More than 1.0° Cooler*	0.5° to 1.0° Cooler	0° to 0.5° Cooler	0° to 0.5° Warmer	0.5° to 1.0° Warmer	More than 1.0° Warmer*	
No. Hem. polar latitudes							1.0
No. Hem. higher mid latitudes							1.0
No. Hem. lower mid latitudes							1.0
No. Hem. subtropical latitudes							1.0
So. Hem. subtropical latitudes							1.0
So. Hem. lower mid latitudes							1.0
So. Hem. higher mid latitudes							1.0
So. Hem. polar latitudes							1.0

*If you judge that there is a significant probability that the temperature change in some latitudinal belt may exceed 1.0° (either cooler or warmer), please indicate the level of change expected along with the probability estimate.

II. TEMPERATURE

- For the preceding major question, please state the line of reasoning for your response, adding any amplifying remarks as you desire, or referencing articles you or other scientists have written that state your position on this subject. Please use the space provided below or a separate sheet.

- Using the self-ranking definitions provided in the instructions, please indicate your level of substantive expertise on this major question.

5–4–3–2–1

- Again using the self-ranking guide, please identify those other respondents whom you would rate as "expert (5)" or "quite familiar (4)" in their answer to this particular question.

EXPERT (5)	QUITE FAMILIAR (4)

III. CARBON DIOXIDE, TURBIDITY, AND CLIMATE

Carbon dioxide, atmospheric particles, etc., have different effects on the atmosphere and do not have the same relative importance in their influence. Indicate the relative weight (using percentages) of each of the factors identified below in influencing global climate over the next 25 years.

		Relative Weight (Percentage)
A.	Carbon Dioxide	________
B.	Fluorocarbons and other gases	________
C.	Smoke	________
D.	Volcanic dust	________
E.	Other Particles (aerosols)	________
		Sum: 100%

III. CARBON DIOXIDE, TURBIDITY, AND CLIMATE

- For the preceding major question, please state the line of reasoning for your response, adding any amplifying remarks as you desire, or referencing articles you or other scientists have written that state your position on this subject. Please use the space provided below or a separate sheet.

- Using the self-ranking definitions provided in the instructions, please indicate your level of substantive expertise on this major question.

5–4–3–2–1

- Again using the self-ranking guide, please identify those other respondents whom you would rate as "expert (5)" or "quite familiar (4)" in their answer to this particular question.

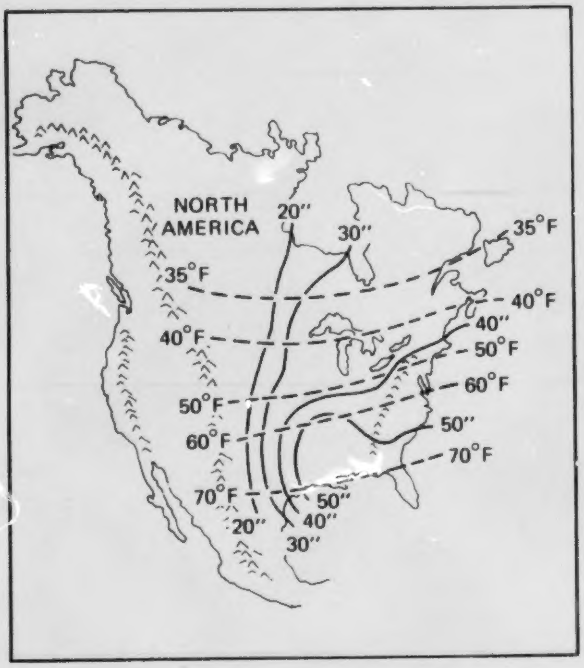
EXPERT (5)	QUITE FAMILIAR (4)

IV. PRECIPITATION

1. Under the alternative assumptions of a temperature change as shown, please fill in each block of the following matrix with your estimate of the probability of change in the mean annual precipitation by the year 2000, as compared with the 1941-70 "normal" pattern, for the regions shown.

2. In your judgment, would these probability estimates be equally as valid for growing season precipitation as for annual totals? (yes ☐; no ☐) If not, please indicate the appropriate probability estimates for changes in growing season precipitation.

3. In many parts of the earth the annual isotherms and annual isohyets tend to run parallel to each other. In North America, however, as Newman and Pickett describe in a 6 December 1974 *Science* article, the effect of the Rocky Mountains range causes the annual isotherms and isohyets to run at approximately 90° to each other, particularly in the midcontinental grasslands region. (See their map, below.) South America is similar to North America in this respect due to the Andes. Newman and Pickett note that:



> *In terms of agricultural production, these climatic features give an advantage to the New World continents. The mean annual isotherms and isohyets, because they are not parallel in the vast grassland climatic areas of the Americas, allow a favorable water balance to be extended over very broad areas in the north-south direction. Also, they allow for agricultural production areas to be less stratified in a north-south direction than they are in the Eurasian continent, and ensure against a slight mean seasonal shift in the prevailing westerly flow; thus, they reduce climatic risk.*

Would these characteristics of the Western Hemisphere region significantly alter your estimates of probability of precipitation change as given in parts 1 and 2 above? If your estimates for North and South America are significantly different from those of the broad latitudinal bands, please indicate the magnitude of these differences in the comments at the end of this question.

PROBABILITY OF PRECIPITATION CHANGE

	Increase by 10% or more*		"No Change" (Less than ± 10%)		Decrease by 10% or more*		Total Probability	
	Annual	Growing Season	Annual	Growing Season	Annual	Growing Season	Annual	Growing Season
Assuming temp. increase of 0.5°C or more								
higher mid-latitudes							1.0	1.0
lower mid-latitudes							1.0	1.0
subtropical latitudes							1.0	1.0
Assuming temp. change of less than ± 0.5°C								
higher mid-latitudes							1.0	1.0
lower mid-latitudes							1.0	1.0
subtropical latitudes							1.0	1.0
Assuming temp. decrease of 0.5°C or more								
higher mid-latitudes							1.0	1.0
lower mid-latitudes							1.0	1.0
subtropical latitudes							1.0	1.0

*If you judge that there is a significant probability that the precipitation change in some latitudinal belt may exceed 10% (increase or decrease), please indicate the level of precipitation change expected along with the probability estimate; also, if the temperature change assumed exceeds 1.0°C, please so indicate.

IV. PRECIPITATION

- For the preceding major question, please state the line of reasoning for your response, adding any amplifying remarks as you desire, or referencing articles you or other scientists have written that state your position on this subject. Please use the space provided below or a separate sheet.

- Using the self-ranking definitions provided in the instructions, please indicate your level of substantive expertise on this major question.

5–4–3–2–1

- Again using the self-ranking guide, please identify those other respondents whom you would rate as "expert (5)" or "quite familiar (4)" in their answer to this particular question.

EXPERT (5)	QUITE FAMILIAR (4)

V. PRECIPITATION VARIABILITY

The report of a climate/food conference in Bellagio, Italy, in June 1975 includes this statement:

> *. . . Temperature change* per se *is not the most serious potential climatic threat to food production. There is a possiblity that, associated with the temperature changes, there will be increased climatic variability. Particularly as such variability increases the fluctuations of precipitation, it poses threats to agricultural production.*
>
> *The climatologists participating in the conference agreed that:*
>
> *1. Climatic variability—region by region and from year to year in particular regions—is and will continue to be great, resulting in substantial variability in crop yields in the face of increasing global food needs and short supplies;*
>
> *2. There is some cause to believe—although it is far from certain—that climatic variability in the remaining years of this century will be even greater than during the 1940-1970 period.*

1. Under the alternative assumptions of temperature change as shown, please fill in each block of the matrix below with your probability estimate that the standard deviation of the mean annual precipitation will change by the indicated amount over the next 25 years, as compared with the average for the previous 25-year period.

2. In your judgment, would these probability estimates be equally as valid for variability in growing season precipitation as for annual totals? (yes ☐; no ☐) If not, please indicate the appropriate probability estimates for changes in variability of growing season precipitation.

3. As noted in part 3 of Question IV above, mountain ranges in North and South America cause the annual isotherms and isohyets to run at approximately 90° to each other in major regions of these continents. If, because of these characteristics, your estimates of the probability of change in precipitation variability in North and South America are significantly different from those of the broad latitudinal bands, please indicate the magnitude of these differences in the comments at the end of this question.

PROBABILITY OF CHANGE IN PRECIPITATION VARIABILITY

	Increase in s.d. by 25% or more*		Less than ± 25% change in s.d.		Decrease in s.d. by 25% or more*		Total Probability	
	Annual	Growing Season	Annual	Growing Season	Annual	Growing Season	Annual	Growing Season
Assuming temp. increase of 0.5° or more								
higher mid-latitudes							1.0	1.0
lower mid-latitudes							1.0	1.0
subtropical latitudes							1.0	1.0
Assuming temp. change of less than ± 0.5° C								
higher mid-latitudes							1.0	1.0
lower mid-latitudes							1.0	1.0
subtropical latitudes							1.0	1.0
Assuming temp. decrease of 0.5° C or more								
higher mid-latitudes							1.0	1.0
lower mid-latitudes							1.0	1.0
subtropical latitudes							1.0	1.0

*If you judge that there is a significant probability that the change in standard deviation may exceed 25% (increase or decrease), please indicate the level of the change expected along with the probability estimate; also, if the temperature change assumed exceeds 1.0°C, please so indicate.

V. PRECIPITATION VARIABILITY

- For the preceding major question, please state the line of reasoning for your response, adding any amplifying remarks as you desire, or referencing articles you or other scientists have written that state your position on this subject. Please use the space provided below or a separate sheet.

- Using the self-ranking definitions provided in the instructions, please indicate your level of substantive expertise on this major question.

5–4–3–2–1

- Again using the self-ranking guide, please identify those other respondents whom you would rate as "expert (5)" or "quite familiar (4)" in their answer to this particular question.

EXPERT (5)	QUITE FAMILIAR (4)

VI. MID-LATITUDE DROUGHT

At a 1975 climatic change symposium at the University of North Carolina, Hurd Willett briefly described the drought pattern of the 1930-1970 period as follows:

> *The warm decade of the thirties witnessed the most severe droughts of the century, in the early to mid-thirities, in many regions of the 35°-50° latitude belt, notably the dust bowl in our western plains, the Russian droughts that triggered liquidation of the Kulaks, severe drought in southern Australia, and in other parts of the world. Note that these droughts occurred in marginal midcontinental as opposed to east coastal regions.*
>
> *The forties were in general a decade of generous rains in the drought regions of the thirties, but with a tendency to substantial deficiency in east coastal regions.*
>
> *The early to mid-fifties, like the thirties, were a markedly dry period in the marginal interior continental regions, notably the American southwestern plains. Severe drought was restricted to latitudes equatorward of 40°. Again, there was a notable tendency to east coastal wetness.*
>
> *The sixties were, like the forties, a decade of generous rainfall in the marginal interior continental regions of middle latitudes, but with some record dry years in extensive east coastal regions. During the sixties and early seventies, the development of severe drought occurred in the middle and lower subtropics, notably in southern Asia and Africa (Sahelian area).*

Willett relates the drought occurrences to a solar-climatic hypothesis of climatic fluctuation, based on an observed relationship between solar and climatic cycles, but recognizing that quantitative physical explanations are as yet nonexistent.

1. With this statement as background, plus your own knowledge and interpretation of past events, please fill in each block of the matrix below with your estimate of the probability of frequency of drought occurrence, for global mid-latitude continental areas.

2. Would your estimates for the United States be significantly different from other mid-latitude continental areas? (yes ☐; no ☐) If so, please indicate probabilities separately for US and other mid-latitudes.

VI. MID-LATITUDE DROUGHT

FREQUENCY OF DROUGHT*

Time period	"Frequent"-i.e., similar to early to mid-1930's and early to mid-1950's		"Average"-i.e., similar to the frequency over the longest period of record available		"Infrequent"-i.e., similar to 1940's and 1960's		Total Probability	
	US	Other mid-latitudes	US	Other mid-latitudes	US	Other mid-latitudes	US	Other mid-latitudes
1977 to 1980							1.0	1.0
1981 to 1990							1.0	1.0
1991 to 2000							1.0	1.0

*There are almost an infinite number of definitions of drought, none of which are completely satisfactory. Drought is defined here as in the December 1973 report to the Administrator of NOAA, ***The Influence of Weather and Climate on United States Grain Yields: Bumper Crops or Droughts:*** "A combination of temperature and precipitation over a period of several months leading to a reduction in yield of the major crops to a level less than 90% of the yield expected with temperature/precipitation near the long-term average values." It should be recognized, however, that yields usually are quoted on a harvested acre basis. In drought years there tends to be a much larger abandonment of crops as well as some deviation in expected yield.

VI. MID-LATITUDE DROUGHT

- For the preceding major question, please state the line of reasoning for your response, adding any amplifying remarks as you desire, or referencing articles you or other scientists have written that state your position on this subject. Please use the space provided below or a separate sheet.

- Using the self-ranking definitions provided in the instructions, please indicate your level of substantive expertise on this major question.

5–4–3–2–1

- Again using the self-ranking guide, please identify those other respondents whom you would rate as "expert (5)" or "quite familiar (4)" in their answer to this particular question.

EXPERT (5)	QUITE FAMILIAR (4)

5 The Food Sector

Introduction

The model used by the U.S. Department of Agriculture (USDA) for its long-range, world food projections is the Grain-Oilseed-Livestock (GOL) model. The GOL model was developed by Anthony S. Rojko and his colleagues at USDA.

The GOL model was first described in a journal article by Rojko and Schwartz in 1976[1] and later in a USDA report.[2] Both descriptions are reprinted here.

The USDA also used three submodels to obtain figures for arable area, total food production and consumption, and total fertilizer use. No documentation for these models is available. What could be learned of these models was explained in a short section in Volume 2,[3] which is reprinted here for completeness.

References

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Editor's note: This section is a reprint of A. S. Rojko and M. W. Schwartz, "Modeling the World Grain-Oilseed-Livestock Economy to Assess World Food Prospects," *Agricultural Economics Research,* vol. 28, July 1976, pp. 89-98.

MODELING THE WORLD GRAIN-OILSEEDS-LIVESTOCK ECONOMY TO ASSESS WORLD FOOD PROSPECTS

By Anthony S. Rojko and Martin W. Schwartz*

Mathematical programming methods are used as a framework to evaluate world food prospects. Emphasis is on analyzing the world grain-oilseeds-livestock economy to capture the interaction of the predominantly cereal economies of the developing world and the livestock economies of the developed world as they compete for the world's agricultural resources. The mathematical model, called the Grain-Oilseeds-Livestock (GOL) model, incorporates general population and income growth rates, demand and supply price elasticities, input variables, and assumptions about basic underlying economic trends and policy constraints.

Keywords: Projections, grain-oilseed-livestock model, trade models.

A model of the world grain-oilseed-livestock economy (GOL) has been developed within the Economic Research Service (ERS) to generate projections of world food production, consumption, and trade to 1985 and 2000.[1] World equilibrium models exist for individual commodities or limited commodity aggregates, and individual country models integrate the grain, oilseed, and livestock sectors. The GOL model, however, is one of the first equilibrium models to consider the broader feed-livestock relationships at the regional and world level. It relates the grain-oriented food economies of developing regions with the livestock-oriented food economies of developed regions in a more complete and logically consistent manner than has been done in the past.[2]

GOL is an operational model used as an integral part of ongoing ERS projections work (*6*). The export projections tie in with detailed U.S. models. It is also used as an analytic tool providing a quantitative dimension to otherwise qualitative international policy analysis.

Using population and income growth rates, supply and demand elasticities, physical input-output rates, and policy assumptions as inputs, the model projects area, production, food and feed use, trade levels, and prices for each commodity. Eleven basic commodities are included: wheat, rice, coarse grains, oilmeal, soybeans, beef and veal, pork, poultry, milk, butter, and cheese. The world was divided into 27 regions: eight developed, three centrally planned, and 16 developing. All regions have some crop equations, but not all regions have livestock equations. The centrally planned regions have collapsed international trade equations only.

The equations in the model were developed to reflect (1) the economic behavioral patterns of the grain-oilseeds-livestock economy, (2) the important technical input-output relationships, and (3) the institutional setting and policy constraints. An attempt was made to model changes in consumption preferences (such as increasing desire for livestock products and increasing use of grain in livestock products and increasing use of grain in livestock production; changes in resource mixes, and changes in both crop and livestock productivity. The individual regional commodity coefficients were synthesized from existing studies and analyses, notably (*3, 5, 11-13, 14, 16, 18, 19, 23* and *24*).

MODEL STRUCTURE[3]

Within GOL, most commodities have supply, demand, and trade sectors modeled. The figure following shows the relationships among the endogenous variables for a typical region. The crop supply sector appears at the far

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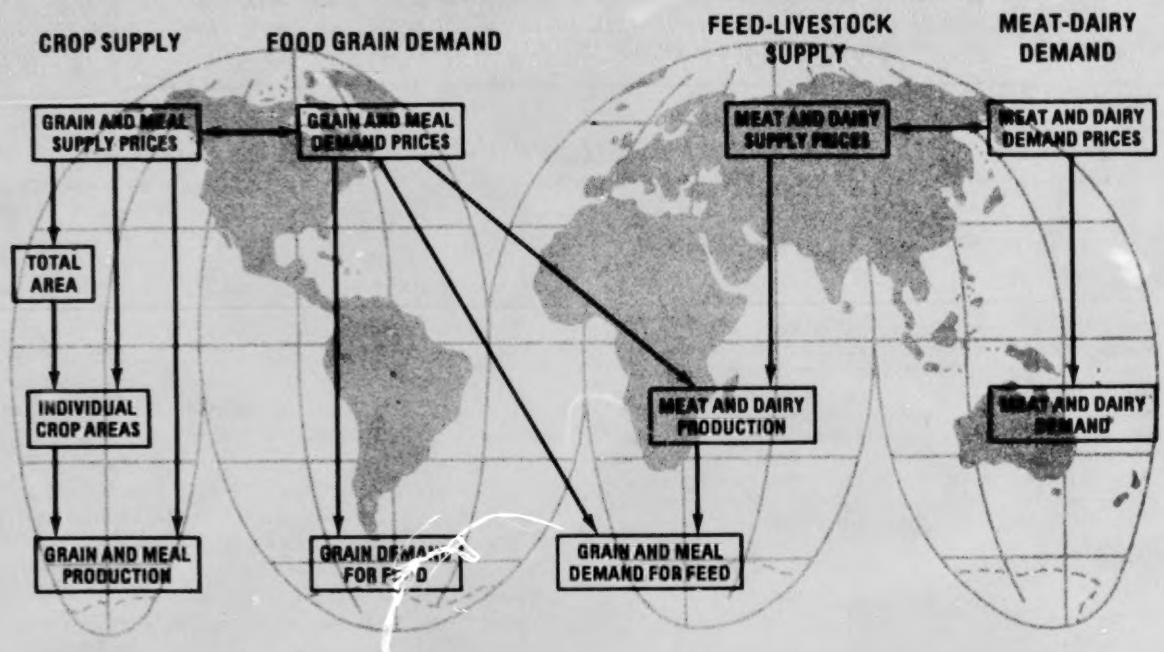
[1] This article reports on one phase of an ongoing research effort aimed at generating and maintaining up-to-date price, production, consumption, and trade projections for the major regions of the world. This effort requires substantial ongoing teamwork from members of the Commodities Program Area working with others in FDCD and other ERS divisions in the area of econometric model development and country-specific analyses. Significant inputs have been made by Donald Regier (livestock), Patrick O'Brien (grains), Arthur Coffing (oilseeds), Robert Barry (rice), Myles Mielke (dairy), and Linda Bailey. Several people have helped to develop the computer programs, beginning with Francis Urban in the early stages, Hilarius Fuchs during the main development stage, followed by Fenton Sands and Martin Schwartz. The work summarized here has been reported in detail in several other ERS publications–(*8, 20-22*). It was discussed in context with other ERS forecasting and projections models in (*6*).

Note: Italicized numbers in parentheses refer to items in References at the end of this article.

[2] A primary purpose in development of the model was to provide a quantitative basis for assessing the world food prospects of the developing world in the context of the total world grain and livestock complex. Several reports (*4, 9, 28*) have been concerned with this issue, as well as two ERS reports (*7*) and (*8*) that used results from this model.

[3] This model builds upon the world grain model developed by Rojko, Urban, and Naive (*20*). The approach has also been influenced by model development by Bawden (*2*), Judge and Takayama (*15, 26, 27*), and others (*10*).

SUPPLY AND DEMAND SECTORS FOR A TYPICAL REGION IN GOL MODEL


CROP SUPPLY
FOOD GRAIN DEMAND
FEED-LIVESTOCK SUPPLY
MEAT-DAIRY DEMAND
GRAIN AND MEAL SUPPLY PRICES
GRAIN AND MEAL DEMAND PRICES
MEAT AND DAIRY SUPPLY PRICES
MEAT AND DAIRY DEMAND PRICES
TOTAL AREA
INDIVIDUAL CROP AREAS
MEAT AND DAIRY PRODUCTION
MEAT AND DAIRY DEMAND
GRAIN AND MEAL PRODUCTION
GRAIN DEMAND FOR FOOD
GRAIN AND MEAL DEMAND FOR FEED

left of the chart. The key endogenous variable is total area, defined as a function of the prices for the region's most important crops. Individual crops compete for total area based on historic shares and projected relative prices of the crops. Production is determined from the area and from crop prices; prices are included to allow response to higher input use when prices are higher. Typical grain supply equations[4] for a region are:

Total area = F (wheat and other crop prices)
Wheat area = (total area, price of wheat, corn, and meal)
Wheat production = F (wheat area, wheat price, exogenous input bundle)

Grains demanded for human food are functions of grain prices, income, and population. The price elasticities allow variance in both total food demand for grain and the relative shares of individual grains. Demand for meats and dairy products, shown on the far right of the chart, are modeled similarly. Typical equations are:

Wheat demand for food = F (price of wheat, corn, price, rice; income; population)
Beef demand = F (price of beef, pork, and poultry; price, income; population)

The feed demand-livestock production sector, second from the right in the figure, is more complex. Meat production is a function of meat prices, feed prices, and productivity. The incorporation of individual meat prices allows competition between the meats. Grain and oilseed feed prices influence the cost of producing meats. Typical equations are:

Beef production = F (price of beef, pork, corn, and meal; productivity)

Feed demand is a function of appropriate grain prices, meat prices, and livestock production. Crop prices allow competition between feeds. The coefficients for livestock products are nominal feeding rates; that is, the tons of grain used to produce a ton of livestock products. Livestock product prices are used to adjust feed demand, essentially modifying the feeding rate, which forms a second set of relations between crop prices and livestock prices. Typical equations are:

Oilmeal demand for feed = F (production of beef, pork, poultry, eggs, and milk, price of pork, corn, and meal)

Supply and demand prices for crops and meats, shown as arrows in the figure, are usually related through constant margins. Price margins fluctuate, however, in the few selected regions where historical data indicates that margins widen, narrow, or do both, as price levels change.

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[4] Note: Crop areas sum to total area in these equations.

Total milk production, similar to that of crops and meat, is a function of milk price, feed prices, and productivity growth. However, dairy products and prices are treated somewhat differently because of the physical production process. Total milk production is processed into cheese or butter or sold as fluid milk products. The supply function for fluid milk is, in fact, also the demand function because fluid demand is filled first. Thus, the function is defined as a function of milk price, income, and population. Production of cheese and butter depends on the relative demand for these products; thus, relative product prices and other demand factors determine their output. Cheese production is a function of cheese and butter price, population, and income. Population and income are included to reflect the continuing longrun growth in demand for cheese. Mathematically, butter production is treated as a residual. Through use of physical conversion factors, total milk production not required for fluid milk and cheese becomes butter. The supply prices of total milk, butter, and cheese and the demand price of fluid milk products are related to reflect product yield.

Economic activity between regions is related through trade prices and a world equilibrium for each commodity traded. The commodity-specific world equilibrium equations state that total world production minus total world demand equals the change in stocks. Stock changes are either predetermined or treated as residual, depending on the purpose of the particular simulation. Each region's import or export prices are related to the region's demand price, either through constant margins or through decreasing margins as trade prices increase. That is, it is assumed that whenever import prices increase, the entire increase will not be passed on to consumers. Finally, trade prices in the different regions are related.

GOL incorporates a number of exceptions to the treatment outlined above. These exceptions are included to more accurately model a particular region. For example, variable levies are included in the equations for the European Economic Community (EC). In addition, special equations linking the original six countries (EC-6) and the new members (EC-3), which are modeled as separate regions, are included to reflect the gradual harmonization provided for in the EC's Common Agricultural Policy. For major exporters, the unusually high response suggested by the supply coefficient at lower levels of total resource use reflects policy actions to withhold area from production. In contrast, the low response indicated at high levels of resource use reflects slowed producer response in an open-market situation. Consequently, many of the coefficients in the over 900 equations of GOL reflect a combination of economic variables as well as policy constraints. Thus, meaningful use and interpretation of output of the model require an understanding of the implications intended.

ALTERNATIVES PRESENTED BY THE MODEL

The GOL model has been used both to assist analysis of broad alternative futures and to assist answering specific questions. The broad alternatives usually specify income growth or technological progress as being faster or slower than expected. Or they specify general changes in import restrictions. The broad alternatives are implemented by changing, uniformly, the income or population growth rates for the developed or developing regions and by changing specific model parameters that represent, for example, import levies. Some specific questions for which runs have been developed are these:

- What would happen to production, consumption, and trade if the U.S. export price of grains were fixed?
- What would result if Brazil added substantially to its oilseed area?

Answering such questions often requires adding additional equations and variables to the model, and, usually, careful consideration of the overall model structure.

STATUS OF MODELING EFFORT

The modeling efforts outlined here are in varying stages of development with regard to:

- Testing the mathematical feasibility of quantifying the interaction of economic, technical, and policy considerations.
- Developing computer capabilities to generate and present alternative futures at reasonable costs
- Exploring the issue of short-term forecasts versus long-run projections
- Establishing linkages to other models that have different aggregations and
- Retaining GOL's stochastic properties and assessing the probabilities of alternative futures.

The GOL model moves beyond previous ERS efforts to developing an ongoing detailed world model with several commodities, one sufficiently flexible to project alternative futures that are internally consistent within and between alternatives. The computer program consists of three parts: (1) a matrix generator to facilitate data input, (2) the MPS-3 programming system for obtaining the solution, and (3) a report writer for presenting results.[5]

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[5] Roger Strickland helped develop the matrix generator (*17, 25*). Current costs for the usual run at USDA's Washington Computer Center are about $20 for the matrix generator, $20 for the solution, and $3 for a printout of the results. Output includes about 30 tables containing data on supply and distribution, prices, per capita production and consumption, and growth rates; and special summary tables.

Level of Detail

GOL's main strength is its level of commodity, regional, and price detail. It provides for resource competition across the crop sector and demand competition among different crops for food and feed use. GOL also incorporates physical input-output rates in the feed-livestock sector and in the crop sector of the developing countries. The regional detail differentiates producing and consuming regions as well as regions at different levels of economic growth and income levels. The model's supply, demand, and trade price detail allows policy flexibility on production and marketing strategies. While the detail incorporated into GOL leads to a number of computational problems, exclusion of any of the model's commodity, region, or price components could reduce cross-commodity and cross-region competition and differentiation.

Limitations

A number of programming limitations affect GOL. The endogenous (simultaneous) part of the model is limited to linear equations. At low price levels, such equations tend to generate very low price response. Nonlinearities are handled by specific changes to the input file; that is, by compensating through coefficient adjustments. Also, the current version of the model does not include a trade matrix or an objective function. Though set in a linear programming (LP) framework, GOL has a square matrix, in which the solution algorithm is used as a matrix inverter. A transportation and transfer matrix and objective function could be added at some later date.

GOL is a static equilibrium model. Though this characteristic may be appropriate for long-term projections, it is not satisfactory for short-term and, possibly, intermediate-term forecasting. Equilibrium point estimates can be made for different projected time periods, but estimates for each period are independent of estimates for any other period. A more ideal system would project a dynamic sequence of estimates, beginning from some current level because some variables (such as stock levels and production shortfalls) are critical in the short and intermediate term. Other variables (such as population and those factors affecting the resource base) would predominate in the longer run. The modeling system should permit testing the impact of a disturbance, such as a production shortfall, at any future point in time in relation to the projected situation at the point of disturbance. Work in this area, taking into account trade flows, is being pursued by Takayama in Illinois and, to a lesser extent, by Johnson at North Carolina State. ERS economists, particularly Kost and Schwartz, are also working to link long-range projections with short-term forecasting in the international area.

Future Refinements Under Consideration

Three methods are currently being considered to solve GOL's programming limitations. First, the number of variables could be reduced by combining some regions or by eliminating the "accounting" variables; that is, those variables which appear only in their definitional equations. Second, the GOL model could be taken out of the LP environment, as other solution algorithms may be preferable. Third, pre- and post-optimization routines could be added to the computational system. For example, it might be desirable to divide the model into subsectors, as explained below. This procedure would reduce the number of variables and equations that would be needed for the LP (or quadratic programming) optimization routine.

Another area needing more study is that of linkages with other international models, whether in terms of inputs or outputs. Linkage questions also arise from problems of aggregation or disaggregation. Factors such as income link the GOL model to a country or region's general economy. However, no provision is made for feedback, which could be important in those developing countries where agriculture is the major sector in the economy. A multicommodity model, in some instances, should also be linked to more global trade models to reflect changes in foreign exchange positions and their impacts on commodity trade. Linkage to a more detailed single-commodity model may also be desirable. Also important is tying the GOL model output into the more detailed ERS core projections system for the United States and providing for cross-model interaction. More formal interaction is needed here.

In the current version of GOL, grains were emphasized, and livestock products received less than full coverage. As more information becomes available, particularly for the developing countries, the livestock sector could be enlarged. This change could require creating separate detailed submodels which could be linked to a more aggregate type of GOL model. Subsector models of this type could be integrated into a collapsed version of GOL in which only the excess supply and demand functions (trade) would be solved simultaneously.

Very little formal analysis has been done to evaluate the stochastic properties and assess the probabilities of alternative GOL projections. This work would require assessing the probabilities of the assumptions as well as the stochastic properties of the model structure. Projecting backward into history might provide some clues. However, projections of alternative futures often involve changes in structures that have no historical record. Further analytical effort is needed to document those parts of the model with stochastic properties and those without them, so that the relative probabilities of the projections can be realistically assessed.

WORLD GRAIN-OILSEEDS-LIVESTOCK ECONOMY, 1985: ASSUMPTIONS

Each of the alternative projections of the GOL model has involved general as well as specific assumptions. Several of them, such as the absence both of major wars and natural disasters, are common to all the alternatives. Incorporating a natural disaster or world war assumption would completely overshadow the relationships within the agricultural sector or the general economy, and it would shape projections to fit exogenous political or humanitarian considerations. The areas covered in some of the basic assumptions are outlined below.

General Assumptions

Population. Population growth is a key variant in demand growth for agricultural products. The United Nations median variant population growth rates, as assessed in 1974 and modified within ERS to reflect subsequent developments, were used for each region. An exception was the United States, for which population is projected according to series III figures from the U.S. Department of Commerce. From 1969-71 through 1985, population is expected to increase 0.8 percent annually in the developed world and 2.7 percent annually in the developing market economies.

Income. Income is another key variant in demand growth for agricultural products. While population may be the single most important demand factor in the developing countries, income is the most significant contributor in the developed nations.

USDA projections use real per capita private consumption expenditure (PCE) or, when PCE data are not available, either gross domestic product or net material product as demand shifters. The basic income projections used in GOL are the projected "trend" income values from the Food and Agriculture Organization's (FAO) 1974 *Assessment*. For the developing countries, FAO rates to 1985 are above the trend levels of the last decade and a half. GOL's alternative projections are based largely on adjustments to those basic income growth rates. In all cases, however, income and price inputs are measured in constant currency units with a 1970 base.

Specific Assumptions

Technology and Inputs. The projections assume that technology will continue to evolve as in the recent past. The developed countries, and, to a lesser extent, the developing countries, will continue to take advantage of technological innovations. Rates of adoption, however, will generally remain limited by the relative costs of inputs, particularly the energy costs assumed to be higher for the projected period than in the past decade. More specific adoption assumptions, particularly for the developing countries, are incorporated into individual GOL alternatives.

Some analysts question whether technological improvements will permit increases in crop yields over the next decade and a half at the rates achieved over the last two decades. However, analyses of growth in grain yields in the major grain-producing regions of the world for 1965-75 fail to substantiate the contention that growth in grain yield is stagnating.

Weather Variability and Stock Change. Weather variations and stock levels are key factors affecting supply availabilities, price fluctuations, and trade levels. Production levels in any one year will be affected by long-term weather trends as well as by year-to-year fluctuations. Alternative stock policies aimed at accumulating and drawing down reserves in periods of surplus or production shortfall can either aggravate or minimize the price and consumption adjustments generated by weather fluctuations.

The GOL alternatives all assume normal weather. Small fluctuations in stocks are associated with a normal weather assumption. If weather patterns deviate substantially from the normal of the last two decades, and if shortfalls occur more often than twice a decade, substantially high production levels in the "good" years would be needed to accumulate sufficient stocks to maintain consumption in "bad" years. Given the probability of shortfalls and specific policies as to how much these would be covered from stocks and how much met by cutbacks in consumption, another GOL alternative could be projected to quantify changes in price, production, consumption and trade levels.

Policy Assumptions. The policies of the major importing countries can affect production, consumption, and trade as much as can the interactions of economic variables. Agricultural and trade policy assumptions are incorporated into the different alternatives, explicitly or implicitly, through adjustments in the coefficients. For example, the total area equation for the major exporting countries has a very responsive price coefficient to reflect the effect of open-market forces as well as likely government action to adjust area to changes in foreign and domestic supply and demand conditions.

The price and stock policies of the major exporting countries are basic to all the alternatives.[4] The major exporting countries are expected to continue their present policies of adjusting production levels and of carrying at least the minimum stocks necessary to keep the world in relative balance rather than to permit sizable surpluses and deficits to develop.

The restrictive trade and domestic agricultural production policies of the major developed importing countries other than Japan are expected to continue through 1985 in GOL's base alternatives. The countries of Western Europe in particular are assumed to maintain at least current self-sufficiency rates through continuation or modification of present food and fiber policies. It is assumed, for example, that the EC will continue to use variable levies to control the flow of imports. It is also assumed that price policies of other Western European countries will result in price levels similar to those in the

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[4] Given the key U.S. role in either the export or import of all the commodities considered in GOL, the appropriate U.S. c.i.f. or f.o.b. price is used as an indicator of world supply and demand conditions.

Community. Possible changes in policy mixes are tested under different alternatives.

The longrun level of U.S. trade with the USSR, People's Republic of China, and Eastern Europe is assumed to be affected more by political than economic factors. Though no special multicommodity trade agreements have been assumed between the United States and the centrally planned countries, the levels of trade projected are in line with the quantities outlined in recent bilateral agreements.

The livestock and poultry economies starting up in most of the developing countries are not assumed to have taken off by 1985. Foot-and-mouth disease, aftosa, will continue to strongly influence trade patterns. As aftosa already exists in both Europe and South America, trade in fresh and frozen meat between these two continents will continue. And because the disease does not exist in Oceania and the United States, they will be able to export to the whole world, but they will not import fresh or frozen meat from any affected areas.

Quotas on beef imports to the United States are assumed to continue. Imports of dairy products to the United States also continue to be limited by quotas. Butter is excluded and some growth in cheese imports is permitted as demand warrants. Because of continued health regulations, other policy factors, and natural developments, fresh milk is assumed not to be traded. Primary adjustments in dairy markets between countries will occur for butter and cheese. It is assumed that their prices can be read as barometers of price pressures in the international dairy situation.

WORLD GRAIN-OILSEEDS-LIVESTOCK ECONOMY, 1985: RESULTS

Overall Conclusions

The general results common to all alternative sets of 1985 projections from GOL generated to date indicate the following:

- Continued growth in economic activity, particularly in the developed countries, would generate a strong and growing demand for meat and livestock products—under all alternatives.
- Per capita meat consumption grows under all alternatives projected; however, per capita consumption stagnates in the developing countries under the low-income growth alternative.
- In the base projection, per capita meat consumption in the commercial sector of the world meat economy is expected to rise from 72 kilograms to an annual average of 78 kilograms in 1985.
- Though expanding demand for livestock products cannot occur without growth in income, national production and trade policies may be more important than income growth in determining world demand and trade levels for meats. Policies stimulating or dampening meat consumption growth in Western Europe and Japan could alter world trade patterns directly, and they could retard or stimulate meat consumption elsewhere indirectly.
- Continuation of present policies would tend to bring high internal price policies and continued barriers to meat imports in Western Europe and Japan, including restrictions on consumption in some developed countries because of high fuel and energy costs.
- Developed countries will continue to be the major meat producers—almost two-thirds of world meat in 1985.
- In the base projection, a 44-percent increase in feed grain allocation is associated with a 36-percent rise in meat production in the developed countries; in the developing countries grain use for livestock feed grows 79 percent while meat production increases 70 percent.
- Projected higher relative feed costs will dampen expansion of meat production unless economies occur in the marketing and production structure of the livestock sector.
- If harmonization of the European Community is fully realized by 1985, the following impacts on trade patterns in meat follow:
  - —The United Kingdom is largely eliminated as an import market for third-country meat as EC members trade more and more with each other.
  - —Australia loses the United Kingdom market but enjoys largely offsetting expansion of exports to the United States, Japan, and elsewhere.
  - —Argentina's loss of the EC market is not directly compensated in the U.S. market because of the aftosa problem.
- The United States continues to be a more important market than Japan and Western Europe for meat imports; if Japan and Western Europe adopt a less restrictive approach, the traditional exporting countries would find markets more encouraging in Western Europe and Japan than in the United States.
- Over the next decade, the world can produce enough grain at reasonable prices to meet the demand of a largely cereal diet in the developing world and a moderately rising feed demand in the developing world.
- World trends in the production of individual grains are expected to continue. Wheat will account for slightly less than a third of the grain total while coarse grains are expected to increase slightly, at the expense of rice, to roughly three-fifths of the total. Approximately two-thirds of the production increase is expected to result from assumed levels of improved yields. The remaining one-third results from increases in area.
- Importing and exporting countries in the developed and centrally planned countries will continue to be

the major producers and consumers of wheat and coarse grains; rice production and consumption will remain concentrated largely in the developing countries.

- The big factor in the growth in demand for grain in the developed countries will be the feed demand generated by an expanding livestock sector.
- Substantial increases in food grain demand are expected over the next decade in the developing market economies, primarily because of an expected 2.7-percent growth in population. Total cereal consumption is projected to rise annually at 3.2 to 3.7 percent.
- The world grain balance hinges largely on the degree to which the lower income developed countries follow the feed usage patterns of the United States and the European Community. If income grows rapidly in the developing countries and it is translated into demand for livestock products, or if the medium and low-income developed countries adopt the livestock techniques of Japan, the European Community and the United States, or if both developments occur, grain prices would be pushed substantially above the base 1970 price level. But as demand for feed tightens available world grain supplies, food demand would be expected to outbid feed demand, particularly in the developing countries.

Specific Conclusions Regarding the Developing Market Economies

Based on results of GOL for all 1985 projections, certain developments are likely in the developing market economies:

- World grain production over the next decade will permit continued improvement in per capita cereal consumption in the developing market economies. Per capita consumption levels are projected to rise from 172 kilograms in the 1970 base to 185 kilograms in 1985 under the base assumptions. Per capita consumption would be as high as 202 kilograms under the high demand, high productivity alternative.
- Production of cereals in the developing market economies is projected to barely exceed the annual population growth rate of 2.7 percent. Growth in production under the high productivity alternatives, however, would average a full 1 percent above the population growth rate.
- The developing countries' import demand is projected to rise from 18 million metric tons in base period to 48 million tons in 1985 under the base alternatives and as high as 68 million tons under the high-demand alternative. Developing countries' imports could be as small as 34 million tons if these countries accelerate production by increasing inputs and adopting updated technology at the rates postulated under the high productivity alternative.

APPENDIX

Details of GOL Model in 1975

The Appendix summarizes GOL's mathematical form and presents one region's equations (pp. 96-97).

In matrix form, the model can be written as:

$$AX = D$$

where A is a coefficient matrix (square) of linear interactions, X is a vector of endogenous variables, and D is a matrix of the exogenous parts of the model.

Though the matrix A must be linear because a linear programming solution is used, matrix D has no such limitations. The form of D depends on the assumptions made with respect to the kind of impact expected from the exogenous or given variables. The impacts may take one or some combination of the following forms:

$$D = C + B\,(1 + R)^T$$
$$D = C + EZ$$
$$D = C + KT$$

The first assumes a compound growth rate is appropriate. B is a vector of bases to be compounded, R represents a set of growth rates for particular exogenous variables, and T is the number of years over which compounding occurs. The second form assumes linear growth in which E is the coefficient matrix and Z, a vector of exogenous variables. The third simply assumes that linear trends prevail.

In the equations, the following code is used:

Characters

First, second	country
Third, fourth	functional designations, such as supply and demand
Fifth, sixth	commodity

European Community (Euro six)

Demand Equations

$$\mathrm{C6QDB} + 2.6972\ \mathrm{C6PDB} - 1.6403\ \mathrm{C6PDP} + .6907\ \mathrm{C6PDZ} = 1{,}448.4 + 4{,}828[1 + .6(.03263) + .00580]^{T}$$

$$\mathrm{C6QDP} - 1.994\ \mathrm{C6PDB} + 4.528\ \mathrm{C6PDP} - .8590\ \mathrm{C6PDZ} = 899.3 + 4{,}997[1 + .5(.03263) + .00580]^{T}$$

$$\mathrm{C6QDZ} - .5814\ \mathrm{C6PDB} - 1.0855\ \mathrm{C6PDP} + 2.934\ \mathrm{C6PDZ} = 363.88 + 1{,}917[1 + 1.0(.03263) + .00580 + .005]^{T}$$

$$\mathrm{C6QDV} - .0276\ \mathrm{C6PDB} - .0392\ \mathrm{C6PDP} + .0594\ \mathrm{C6PDV} = -\ 11.46 + 231[1 + .00580]^{T}$$

$$\mathrm{C6QDLM} + 76.52\ \mathrm{C6PDLM} = 7{,}881.6 + 31{,}526[1 + .2(.03263) + .00580]^{T}$$

$$\mathrm{C6QDLB} + 4799\ \mathrm{C6PDLB} = 837.91 + 1{,}197[1 + .2(.03263) + .00580]^{T}$$

$$\mathrm{C6QDLC} + .7591\ \mathrm{C6PDLC} = 1{,}099.2 + 1{,}832[1 + .5(.03263) + .00580]^{T}$$

$$\mathrm{C6QDWH} + 44.46\ \mathrm{C6PDW} = 4{,}460.2 + 22{,}300[1 - .1(.03263) + .00580]^{T}$$

$$\mathrm{C6QDCH} + 21.38\ \mathrm{C6PDC} = 1{,}964.8 + 9{,}825[1 + .1(.03263) + .00580]^{T}$$

$$\mathrm{C6QDRH} + .5425\ \mathrm{C6PDR} = 181.19 + 604[1 + .2(.03263) + .00580]^{T}$$

$$\begin{aligned}\mathrm{C6QDGF} - 1.3\ \mathrm{C6QSB} - 3.6\ \mathrm{C6QSP} - 2.7\ \mathrm{C6QSZ} - .25\ \mathrm{C6QSV} - .1248\ \mathrm{C6QSL} - 3.1\ \mathrm{C6QSE} - 30.92\ \mathrm{C6PSP}\\ + 253.67\ \mathrm{C6PDC} - 45.72\ \mathrm{C6PDK} = -\ 51{,}128.84 + 46{,}625[1 + .005]^{T}\end{aligned}$$

$$\mathrm{C6QDWF} - .185\ \mathrm{C6QDGF} + 20\ \mathrm{C6PDW} + 50\ \mathrm{C6PTW} - 50\ \mathrm{C6PTC} = 2{,}150.28$$

$$\mathrm{C6QDCF} + \mathrm{C6QDWF} - \mathrm{C6QDGF} = 0$$

$$\begin{aligned}\mathrm{C6QDKF} - .16\ \mathrm{C6QSB} - .67\ \mathrm{C6QSP} - 1.18\ \mathrm{C6QSZ} - .0326\ \mathrm{C6QSL} - .71\ \mathrm{C6QSE} - 17.8\ \mathrm{C6PSP} - 103.3\ \mathrm{C6PDC}\\ + 25.40\ \mathrm{C6PDK} = -\ 30{,}474.74 + 10{,}546[1 + .004]^{T}\end{aligned}$$

Supply Equations

$$\mathrm{C6QSB} - 2.27\ \mathrm{C6PSB} + .8785\ \mathrm{C6PSP} - 6.431\ \mathrm{C6PSL} + 9.6104\ \mathrm{C6PDC} + 4.3307\ \mathrm{C6PDK} = -\ 441.6 + 4{,}416[1 + .02]^{T}$$

$$\mathrm{C6QSP} + 1.952\ \mathrm{C6PSB} - 4.698\ \mathrm{C6PSP} + 3.098\ \mathrm{C6PSZ} + 22.028\ \mathrm{C6PDC} + 9.926\ \mathrm{C6PDK} = 2{,}530.9 + 5{,}091[1 + .024]^{T}$$

$$\mathrm{C6QSZ} + .494\ \mathrm{C6PSB} + .509\ \mathrm{C6PSP} - 2.743\ \mathrm{C6PSZ} + 8.356\ \mathrm{C6PDC} + 5.649\ \mathrm{C6PDK} = 768.0 + 1{,}920[1 + .044]^{T}$$

$$\mathrm{C6QSV} + .0376\ \mathrm{C6PSB} - .284\ \mathrm{C6PSL} + .3183\ \mathrm{C6PDC} - .0602\ \mathrm{C6PSV} = 165.74$$

$$\mathrm{C6QSE} = 2{,}576[1 + .00580]^{T}$$

$$\mathrm{C6QSL} - 8.425\ \mathrm{C6PSB} - 252.9\ \mathrm{C6PSL} + 404.9\ \mathrm{C6PDC} + 218.9\ \mathrm{C6PDK} = -\ 3{,}721.96 + 74{,}412[1 + .003]^{T}$$

$$\mathrm{C6QSLC} = 1{,}859[1 + .5(.03263) + .010]^{T}$$

$$\mathrm{C6QSL} - \mathrm{C6QDLM} - 22.935\ \mathrm{C6QSLB} - 7.105\ \mathrm{C6QSLC} = 0$$

$$\mathrm{C6HAT} - 29.05\ \mathrm{C6PSC} = -\ 2{,}192.7 + 21{,}925[1 - .75(.03263) + .025]^{T}$$

$$\mathrm{C6HAW} - 71.32\ \mathrm{C6PSW} + 91.67\ \mathrm{C6PSC} - .435\ \mathrm{C6HAT} = 347.41 - 80\ T$$

$$\mathrm{C6HAC} + 71.32\ \mathrm{C6psw} - 91.67\ \mathrm{C6PSC} - .530\ \mathrm{C6HAT} = -\ 295.035 + 80\ T$$

$$\mathrm{C6HAR} - .2157\ \mathrm{C6PSR} = -\ 38.791 + 194[1 + .003]^{T}$$

$$\mathrm{C6QSW} - 81.26\ \mathrm{C6PSW} - 3.19\ \mathrm{C6HAW} = -\ 1.574.99 - 63.07\ \mathrm{C6ZI} + 875\ T$$

$$\mathrm{C6QSC} - 156.18\ \mathrm{C6PSC} - 3.47\ \mathrm{C6HAC} = -\ 3{,}932.2 - 78.59\ \mathrm{C6ZI} + 1{,}260\ T$$

$$\mathrm{C6QSR} - .735\ \mathrm{C6PSR} - 3.41\ \mathrm{C6HAR} = 65.58 - 1.983\ \mathrm{C6ZI} + 6\ T$$

$$\mathrm{C6QSK} = 549 + 10\ T$$

Regional Equilibrium Conditions

$$-\ \mathrm{C6QSB} + \mathrm{C6QDB} + \mathrm{C6QTB} = 0$$

$$-\ \mathrm{C6QSP} + \mathrm{C6QDP} + \mathrm{C6QTP} = 0$$

$$-\ \mathrm{C6QSZ} + \mathrm{C6QDZ} + \mathrm{C6QTZ} = 0$$

$$-\ \mathrm{C6QTZ} - \mathrm{C3QTZ} = -\ 44.0$$

$$-\ \mathrm{C6QSV} + \mathrm{C6QDV} + \mathrm{C6QTV} = 0$$

$$-\ \mathrm{C6QSLM} + \mathrm{C6QDLM} + \mathrm{C6QTLM} = 0$$

European Community (Euro six)--Continued

Regional Equilibrium Conditions (Continued)

$- \mathrm{C6QSLB} + \mathrm{C6QDLB} + \mathrm{C6QTLB} = 0$

$- \mathrm{C6QSLC} + \mathrm{C6QDLC} + \mathrm{C6QTLC} = 0$

$- \mathrm{C6QSW} + \mathrm{C6QDWH} + \mathrm{C6QDWF} + \mathrm{C6QTW} = 0$

$- \mathrm{C6QSC} + \mathrm{C6QDCH} + \mathrm{C6QDCF} + \mathrm{C6QTC} = 0$

$- \mathrm{C6QSR} + \mathrm{C6QDRH} + \mathrm{C6QTR} = 0$

$- \mathrm{C6QSK} + \mathrm{C6QDKF} + \mathrm{C6QTK} = 0$

Supply-Demand Price Equations

$\mathrm{C6PSB} - .7\ \mathrm{C6PDB} = 100.9 - 200[1 + .2(.03263)]^{T}$

$\mathrm{C6PSP} - .8\ \mathrm{C6PDP} = 197.6 - 150[1 + .2(.03263)]^{T}$

$\mathrm{C6PSZ} - .7\ \mathrm{C6PDZ} = 150.7 - 150[1 + .1(.03263)]^{T}$

$\mathrm{C6PSV} - \mathrm{C6PDV} = 0$

$\mathrm{C6PSL} - .1324\ \mathrm{C6PSR} = - .3\ T$

$\mathrm{C6PSW} - \mathrm{C6PDW} = - 3.30$

Demand-Supply Price Equations

$\mathrm{C6PDLM} - \mathrm{C6PSL} = 0$

$\mathrm{C6PDLB} - 22.935\ \mathrm{C6PSL} = - 616.305$

$\mathrm{C6PDLC} - 7.105\ \mathrm{C6PSL} = 716.185$

Demand-Trade Price Equations

$\mathrm{C6PDB} - \mathrm{C6PTB} - \mathrm{C6PLB} = 0 + 209[1 + .3(.03263)]^{T}$

$\mathrm{C6PDP} - \mathrm{C6PTP} - \mathrm{C6PLP} = - 150.0 + 150[1 + .3(.03263)]^{T}$

$\mathrm{C6PDV} - 1.2\ \mathrm{C3PTV} = 0 + 134.4[1 + .3(.03263)]^{T}$

$\mathrm{C6PDW} - \mathrm{C6PTW} - \mathrm{C6PLW} = - 21.82$

$\mathrm{C6PDC} - \mathrm{C6PTC} - \mathrm{C6PLC} = - 5.63 + .3\ T$

$\mathrm{C6PDR} - \mathrm{C6PTR} - \mathrm{C6PLR} = 2.64$

$\mathrm{C6PDK} - \mathrm{C6PTK} = 0$

Price Equations Variable Levy

$\mathrm{C6PLB} + .2\ \mathrm{C6PTB} = 159.0 + 249[1 + .3(.03263)]^{T}$

$\mathrm{C6PLP} + .2\ \mathrm{C6PTP} = 117.2 + 297[1 + .3(.03263)]^{T}$

$\mathrm{C6PLW} + .2\ \mathrm{C6PTW} = 13.04 + 45[1 + .1(.03263)]^{T}$

$\mathrm{C6PLC} + .2\ \mathrm{C6PTC} = 12.36 + 29[1 + .1(.03263)]^{T}$

$\mathrm{C6PLR} + .2\ \mathrm{C6PTR} = 30.91 + 100[1 + .1(.03263)]^{T}$

Regional Price Equations

$\mathrm{C3PDZ} - 1.4\ \mathrm{C6PSZ} = - 127.4 + 77.4\ \mathrm{DVZ} + 3\ T$

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ALTERNATIVE FUTURES FOR WORLD FOOD IN 1985

VOLUME 1, WORLD GOL MODEL ANALYTICAL REPORT

By

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INTRODUCTION

The wide fluctuations in food supplies of the last few years—from surplus to shortage and back to surplus—have focused attention on a number of longer term world food problems that had been submerged during most of the last two decades. The most important of these problems has been the increasing dependence of the developing countries on the developed countries for imports of food. A second problem has been the sporadic but increasingly large grain purchases of the centrally planned economies. Still another problem arises from the increasing use of grain and other concentrate feeds in the production of meat and other livestock products.

Until 1972, the impact of these problems was largely mitigated by the extensive stocks held by the major grain exporting countries, particularly the United States. The increasing dependence of the developing world on both commercial and concessional imports, the increased import demand of the centrally planned countries, and the expansion of grain-fed livestock production in the developed world permitted the exporting countries to reduce surpluses resulting from farm income support programs. But the use of concessional food aid shipments as part of the exporters' surplus management program, and the low food price policies made possible by the developing countries' concessional imports, dampened incentives to produce food in a number of developing countries. The stock drawdown policies and tighter production controls implemented by the United States and the other major exporters in the late 1960's and early 1970's reduced their grain stocks even further, made more grain available to food importers, and encouraged more extensive use of grain in livestock production in the feed importing countries.

Production shortfalls in the USSR in 1972, followed by the Soviet's decision to import enough grain to maintain high consumption levels, combined with shortfalls in other parts of the world, depleted world stock reserves. Production shortfalls in the United States in 1974 and in the Soviet Union again in 1975 could not be made up through stock drawdowns. The world was consequently left dependent on annual production to meet current food needs.

Marked improvements in production in 1975/76 and again in 1976/77 virtually reversed the world food situation by the beginning of 1977/78. With world supplies up and consumption lagging, world stocks of grain hit a decade high, while stocks in the United States hit a 15-year high. This pronounced shift back toward abundance has not solved the problems that generated the world's 1972/73-1975/76 food crisis. Recent short-term improvements in world food supplies could well worsen the world food problem in the longer term by making supply management in the exporting countries more difficult and by disguising problems in the deficit areas of the world as opportunities to dispose of excess supplies.

The recent phenomenon of widely fluctuating food prices and uncertain food supplies that arose out of this combination of weather related production shortfalls, policy changes, and long-term trends raises the following important issues:

--Will the developing world continue to increase its dependence on the developed world for food imports?

--What will be the balance between the developed and developing world? Imports of food versus imports of agricultural inputs and technology?

--What will be the pattern of adjustment forced on the world's commercial meat economy by rising grain prices?

--What will be the relationship between grain use for food and grain use for feed and how will it differ among regions?

--Do the major exporters of grain have the long range capacity to meet the world's growing demand at reasonable prices?

This publication addresses these and other questions through the use of a mathematical model to project world production, consumption, trade, and prices of grains, oilseeds, and livestock products to 1985 under several different alternatives.1/ These projections should not be interpreted as forecasts of the future. The probability that a particular set of projections will materialize depends on the likelihood of its specific assumptions and the basic relationships underlying the projections. Moreover, long-range projections or basic assumptions and relationships can be invalidated over time, particularly if the attention they draw to developing disequilibria is followed by corrective action.

The major alternative sets of projections evaluated in this study can be summarized as follows:

--Alternative I assumes a modified continuation of trends and basic agricultural and trade policies around the world. International trade is somewhat restricted by protectionist national economic policies, but not all trade restrictive goals are met.

--Alternative I-A assumes the successful implementation of alternative I's protectionist policies in the developed countries and slowed economic growth in the developing countries.

1/ For other studies concerned with these problems see pp. 79-83.

--Alternative II assumes high income growth rates that generate substantially higher levels of world import demand.

--Alternative III quantifies the effects of generalized slowed income growth and low world import demand in conjunction with alternative I-A's restrictive trade policies.

--Alternative IV tests out the case of moderately higher productivity in the developing countries in the context of high income growth rates and strong world import demand.

--Alternative IV-A tests out the case of accelerated productivity in the developing countries in the context of high income growth rates and strong world import demand.

In addition, separate runs were made to capture how adverse longrun climatic change, as reflected by lower grain yields, might affect the world grain supply-demand balance and resources availability. Separate runs were also made to capture the effects of more frequent crop production shortfalls, caused by bad weather, than occurred in the two decades prior to 1972. Results of this analysis were used to determine the amount of additional productive capacity needed to build stocks in the "good" years to maintain consumption in "bad" years. In both cases, these parametric runs were tested using each of the alternative I, II, and IV assumptions.

ANALYTICAL FRAMEWORK

The research reported on in this study is based on a formal mathematical model used to project key economic variables in the world's grain, oilseed, and livestock sectors. This report concentrates on the model's projections to 1985. [2] Mathematical relationships underlying the model were specified to capture the interaction of production, consumption, trade, and prices of grain, oilseed, and livestock products.

These mathematical relationships may be grouped into nine major components:

1. Demand block--livestock
2. Supply block--livestock
3. Demand block--feed
4. Demand block--food grains
5. Supply block--crops
   Area
   Production
6. Price linkages within regions

---

[2] This model builds upon the world grain model by Rojko, Urban, and Naive (167) and the approach used has been influenced by model development of Bawden (1007), Takayama and Judge (1069), (1070), and others.

7. Regional equilibrium
8. Price equations linking regions
9. World equilibrium equations for each commodity

Each component of the model may be thought of as consisting of two basic parts: a driving and a responding part.

The driving part of the model is made up of those variables whose levels are determined outside of the model. Included here are the usual demand shifters, such as population and income growth rates, and consumer preference variables, which are usually expressed as trend values. Also included are the usual supply shifters, including technology variables, statements on the availability and cost of basic agricultural inputs, factors related to national commercial and agricultural policies and practices, and basic growth rates for yields derived from analyses of data for the 1950's, 1960's, and early 1970's. The specific equations of each of the model's components specify the levels of the driving variables, as well as the extent to which changes in these levels affect the variables in the responding part of the model.

The responding part of these components are 930 interacting variables that are being projected and are contained in 930 equations specifying supply-demand balances for up to 14 separate commodities in 28 regions of the world. In general, the parameters defining the interrelationships do not vary between alternative projection runs. The demand blocks consist of direct and cross demand-price elasticities. The demand block for feed also includes physical input-output coefficients relating it to the supply block for livestock products. The supply block for livestock contains direct and cross supply-price elasticities. The supply block for crops distinguishes between area and production and allows for area allocation between crops subject to total area for these crops. The production equation allows for yield response to changes in relative prices. The price linkage and the equilibrium components relate the model within regions and among regions. This responding part of the model is solved simultaneously for given levels of the driving variables and is essentially unconstrained. Base data centered on the year 1970 were provided for the interacting variables and their counterpart values were projected for 1985.

The parameters for the model's mathematical relationships were synthesized from either statistical analyses or the judgment of experts. The model could not be a product of a direct statistical fit because of its size. Instead, to facilitate comparisons and permit evaluation of different alternatives, the model was built as an integrated framework of synthesized coefficients describing the behavior of the world's grain-oilseed-livestock sectors. The synthesized coefficients used in the model's equations were developed from numerous sources and adjusted when necessary to reflect relationships among the variables. Data for 1969/70-1971/72 were used to determine the value of the constants in the equations. But while the 3-year average 1969/70-1971/72 was used as base for projections to 1985, developments through 1975/76 were used to evaluate model inputs and projection outputs.

The mathematical model, with the aid of a computer program, projects a set of equilibrium values for production, consumption, trade, and prices of grains, oilseeds, livestock, and livestock products; area, yield, and food and feed use values are also projected for grains and oilseeds. The computer program solves a set of simultaneous equations consistent with the specific alternative under consideration. The equations are specified by commodity, by region, and according to economic function. They consequently constitute quantified descriptions of the world's grain-oilseed-livestock economy. The equations, as well as the supply distribution tables for the individual alternatives, are being published in separate volumes. The parameters underlying the equations—that is, direct and cross supply and demand price elasticities and income elasticities of demand--are presented in a later section of this report.

The scope and organization of economic relationships contained in the model are shown in table 1 and figures 1-2. The variable patterns for each of the model's regions are laid out in table 1. Grains and oilmeals are modeled in all 28 regions of the world (see p. 9). Table 2 lists the countries included in each of the model's regions. Production and acreage equations were not developed for all regions; for instance, only international trade relationships were developed for the three centrally planned regions. Fuller representation of the centrally planned regions will be incorporated in future modeling phases. Minor departures from full coverage in the other 25 regions are deliberate and reflect judgments about the relative importance of a commodity in a specific region and the availability of data.

Modeling of the livestock economy has concentrated, at this stage, on representing the commercially important part of the world's livestock economy. The focus has been on beef and on the developed countries and Latin America. Attention has also been given to other meats and dairy products as competing and complementary products and as close substitutes in consumption.

Figures 1 and 2 present schematic views of (1) a region with both a crop and livestock sector, and (2) a region containing a crop sector only. Differences in the modeling approach can be summarized by highlighting the treatment of the animal sector. Where there are complete crop and livestock sectors, separate production, consumption, and trade balances are calculated for both the crop and livestock sectors, with production of livestock products linked technically to the quantities of a specific crop produced for livestock feed. As a result, world trade for the crops as well as for the livestock commodities is calculated. In regions containing only a crop sector, factors explaining the consumption and production of livestock products are considered to operate directly on the derived demand for crops used as livestock feed. In such regions, no livestock balance and no foreign trade in livestock commodities are calculated.

ASSUMPTIONS

Each alternative projection set has its own bundle of assumptions concerning key economic variables and policy considerations. These are discussed in detail on pages 32-62, where the results of the alternative projection sets are presented. Assumptions general to all projection sets are discussed below. As is usual, the projections assume the absence of major wars and natural disasters that would change the underlying factors affecting future supply and demand prospects.

Population

Population is a key variant in the model's projection of growth in demand for agricultural products. The United Nations' "medium" variant population projections, as reassessed in 1974, were used for all regions except the United States, for which the lower Series III figures of the Department of Commerce were used (table 3 and fig. 3).

World Grain-Oilseed-Livestock Economy

**Region with
Full Livestock Sector**

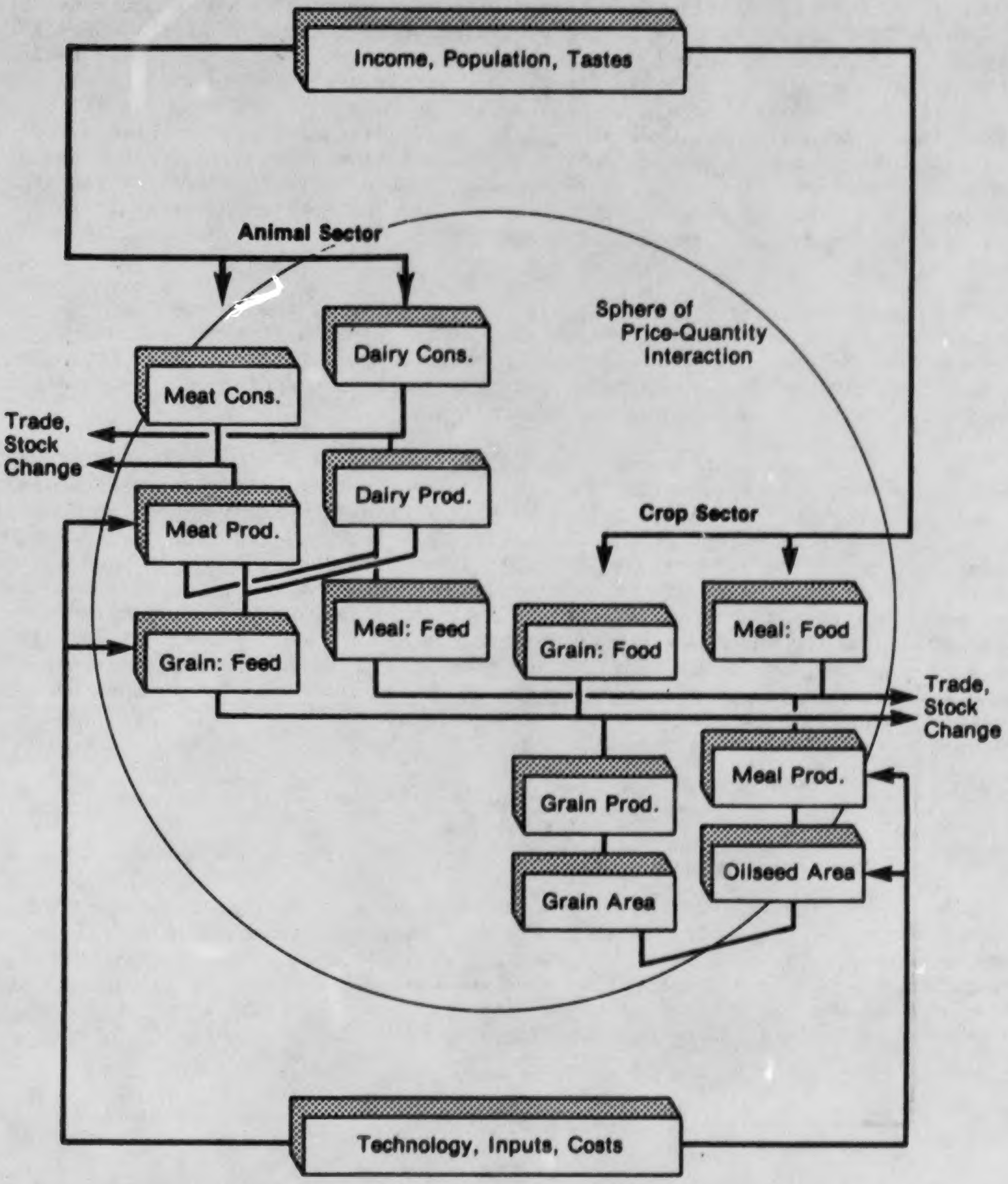

Income, Population, Tastes
Animal Sector
Sphere of
Price-Quantity
Interaction
Dairy Cons.
Meat Cons.
Trade,
Stock
Change
Dairy Prod.
Meat Prod.
Crop Sector
Meal: Feed
Grain: Food
Meal: Food
Grain: Feed
Trade,
Stock
Change
Meal Prod.
Grain Prod.
Oilseed Area
Grain Area
Technology, Inputs, Costs

Figure 1

World Grain-Oilseed-Livestock Economy

Region with
Collapsed Livestock Sector

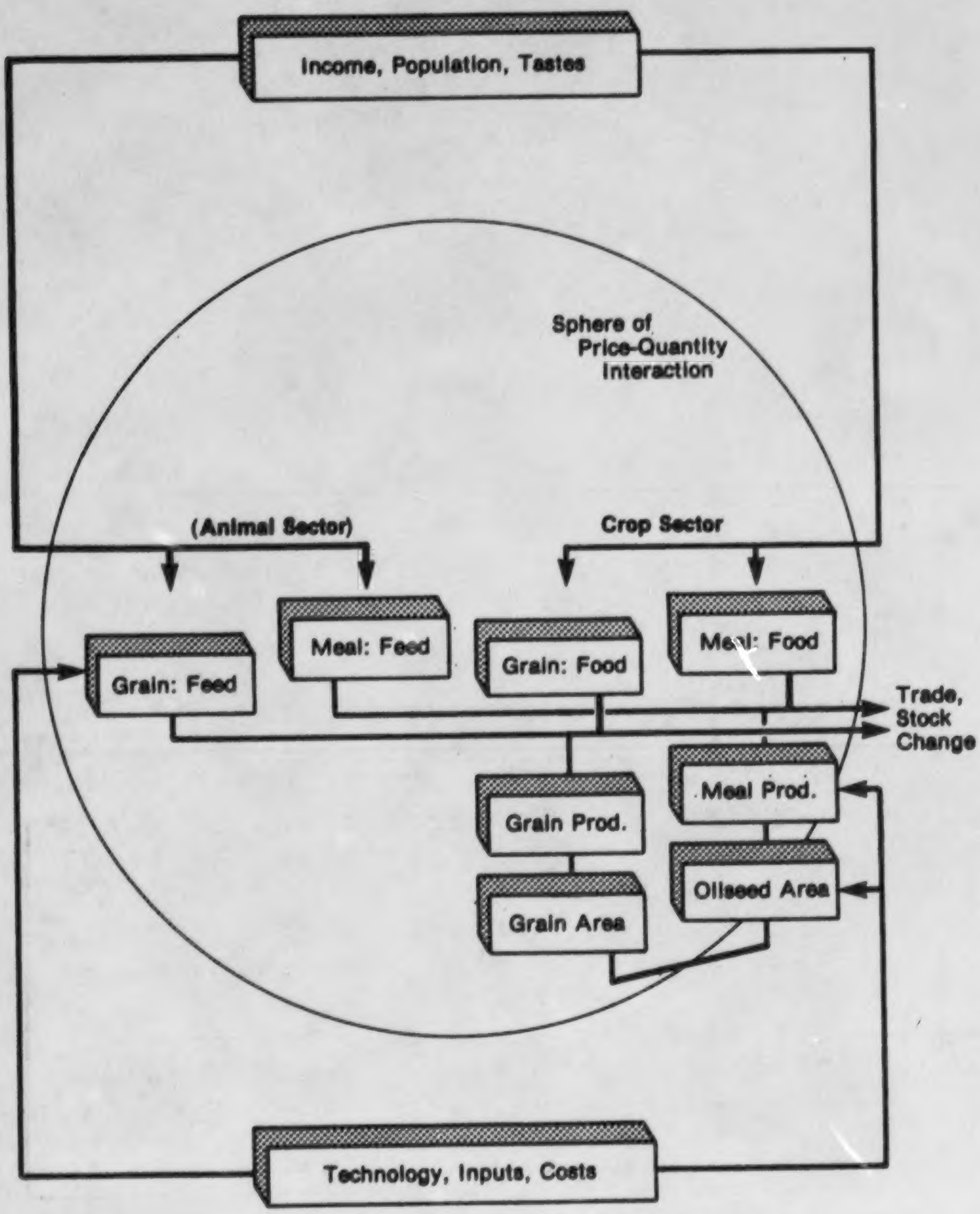

Income, Population, Tastes
Sphere of
Price-Quantity
Interaction
(Animal Sector)
Crop Sector
Meal: Feed
Grain: Feed
Grain: Food
Meal: Food
Trade,
Stock
Change
Meal Prod.
Grain Prod.
Oilseed Area
Grain Area
Technology, Inputs, Costs

Figure 2

Table 1--Variables used in world grain-oilseeds-livestock model

Region	Wheat	Rice	Coarse grain	Oilseed meal	Milk	Cheese	Eggs	Beef cuts	Beef products	Pork	Poultry	Mutton & lamb
Developed countries:												
United States	DF PA	D PA	DF PA	F PA	D S	D S	P	D P	D P	D P	D P	D
Canada	DF PA	D	DF PA	F PA	D S	D S	P		D P	D P	D P	
EC-6	DF PA	D PA	DF PA	F PA	D S	D S	P		D P	D P	D P	D P
EC-3	DF PA	D PA	DF PA	F PA	D S	D S	P		D P	D P	D P	D P
Other Western Europe	DF PA	D PA	DF PA	F PA	D S	D S			D P	D P	D P	D P
Japan	D PA	DF PA	DF PA	DF PA	D S	D S	P		D P	D P	D P	D P
Australia/New Zealand	DF PA	D PA	DF PA	F PA	D S	D S	P		D P	D P	D P	D
South Africa	D PA	D	DF PA	F S		D S			D P	D P	P	D P
Centrally planned countries:												
Eastern Europe	T	T	T	T					T	T		
Soviet Union	T	T	T	T					T			
China	T	T	T	T						T		
Developing countries:												
Middle America	DF PA	D PA	DF PA	F PA					D P	D P		
Argentina	D PA	D PA	DF PA	F PA					D P	D P		D P
Brazil	D PA	D PA	DF PA	F PA					D P	D P		
Venezuela	D PA	D PA	DF PA	F PA								
Other South America	D PA	D PA	DF PA	F PA								
High-income North Africa & Middle East	D PA	D PA	DF PA	F								
Low-income North Africa & Middle East	D PA	D PA	DF PA	S								
East Africa	D PA	D PA	DF PA									
Central Africa	D S	D S	D S	T								
India	D PA	D PA	DF PA	F PA								
Other South Asia	D PA	D PA	D PA									
Thailand	D	D PA	DF PA									
Other Southeast Asia	D	D PA	DF S									
Indonesia	D	D PA	D PA	D PA								
High-income East Asia	D PA	D PA	DF PA	F PA								
Low-income East Asia	D	D PA	DF PA	S								
Rest of world						T			T	T		T

D = Demand, total or nonfeed
F = Derived demand for feed
P = Production
A = Area
S = Supply
T = Foreign trade, net

Table 2--Country composition of regions in the world grain-oilseeds-livestock model

Regions	Composition
I. Developed countries:	
United States	United States
Canada	Canada
EC-6	Belgium, France, West Germany, Italy, Luxembourg, Netherlands
EC-3	Denmark, Ireland, United Kingdom
Other Western Europe	Austria, Finland, Greece, Iceland, Malta, Norway, Portugal, Spain, Sweden, Switzerland
Japan	Japan
Oceania	Australia, New Zealand
South Africa	Botswana, Lesotho, Namibia, Republic of South Africa, Swaziland
II. Centrally planned countries:	
Eastern Europe	Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, Yugoslavia
Soviet Union	Soviet Union
China	People's Republic of China
III. Developing countries:	
Middle America	Mexico, Bahamas, Bermuda, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, British Honduras, Jamaica, Nicaragua, Panama, Trinidad & Tobago, Other Caribbean Islands
Argentina	Argentina
Brazil	Brazil
Venezuela	Venezuela
Other South America	Bolivia, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Surinam, Uruguay

Continued--

Table 2--Country composition of regions in the world grain-oilseeds-livestock model --Continued

High-income North Africa and Middle East	Algeria, Bahrain, Cyprus, Iran, Iraq, Israel, Kuwait, Libya, Oman, Qatar, Saudi Arabia, United Arab Emirates
Low-income North Africa and Middle East	Egypt, Jordan, Lebanon, Morocco, Sudan, Syria, Tunisia, Turkey, Yemen (Aden), Yemen (Sana)
East Africa	Kenya, Malagasy Republic, Malawi, Mozambique, Rhodesia, Tanzania, Uganda, Zambia
Central Africa	Angola, Burundi, Cameroon, Central African Empire, Chad, Congo, Ethiopia, Djibouti, Benin, Gabon, Gambia, Ghana, Guinea, Equatorial Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritana, Mauritius, Niger, Nigeria, Reunion, Rwanda, Senegal, Sierra Leone, Somalia, Togo, Upper Volta, Zaire
India	India
Other South Asia	Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, Sri Lanka
Thailand	Thailand
Other Southeast Asia	Burma, Cambodia, Laos, South Vietnam 1/
Indonesia	Indonesia
High-income East Asia	Hong Kong, Singapore, South Korea, Taiwan, Brunei
Low-income East Asia	Malaysia, Philippine Islands
Rest of world	North Korea, North Vietnam 1/, Mongolia, Cuba, Pacific Islands, Papua-New Guinea

1/ The model was designed before the reunification of North and South Vietnam into the People's Republic of Vietnam.

Table 3--World population and growth rates, average, 1969-71, and projected, 1985

Region	Population levels		Compound annual growth rates
	1969-71 average	1985 projection	
	Thousands		Percent
Developed countries:	700,346	792,229	.836
United States	204,880	228,360	.726
Canada	21,030	26,045	1.436
EC-6	188,084	205,127	.580
EC-3	63,381	67,393	.410
Other Western Europe	82,021	89,921	.615
Japan	104,330	122,443	1.073
Australia/New Zealand	15,320	19,929	1.769
South Africa	21,300	33,011	2.964
Centrally planned countries:	1,126,189	1,377,782	1.354
Eastern Europe	125,629	139,486	.700
Soviet Union	242,760	283,010	1.028
China	757,800	955,286	1.556
Developing countries:	1,734,192	2,591,070	2.680
Middle America	78,844	124,691	3.103
Argentina	24,160	29,173	1.265
Brazil	94,660	144,245	2.848
Venezuela	10,788	16,681	2.948
Other South America	61,780	92,940	2.760
High-income North Africa & Middle East	62,752	101,018	3.225
Low-income North Africa & Middle East	116,479	177,518	2.849
East Africa	57,534	90,027	3.030
Central Africa	179,755	270,382	2.759
India	564,810	814,420	2.470
Other South Asia	172,100	269,024	3.023
Thailand	37,160	60,458	3.298
Other Southeast Asia	56,000	79,505	2.364
Indonesia	119,720	177,000	2.641
High-income East Asia	50,280	67,154	1.948
Low-income East Asia	47,370	76,834	3.277
Rest of world	46,740	(66,964)	(2.426)
World	3,607,467	(4,828,045)	(1.9454)

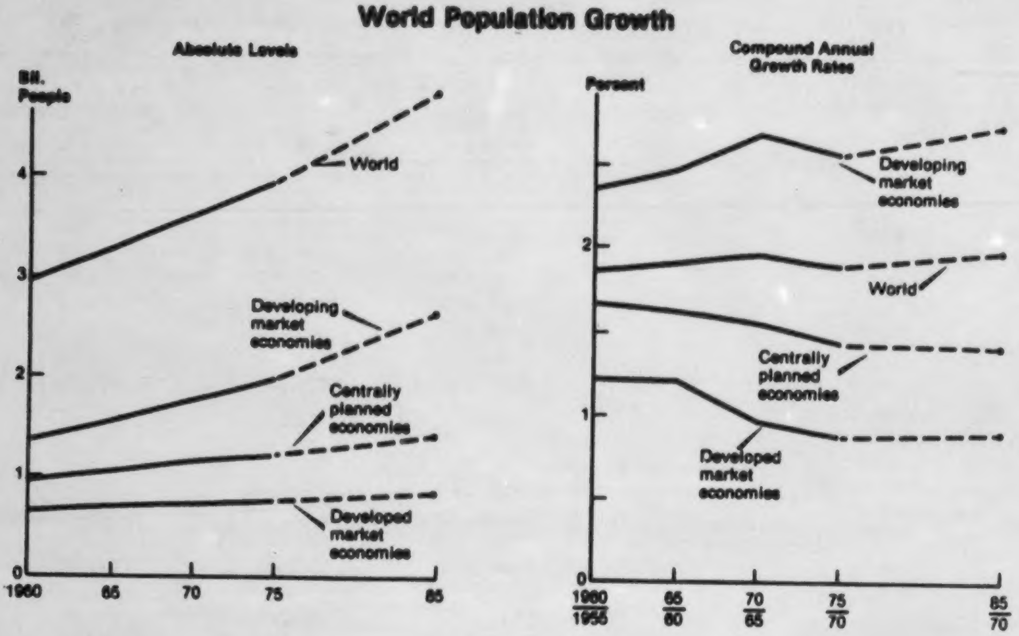


Figure 3

Over the projection period, 1969-71 through 1985, population is expected to increase at an annual rate of 0.8 percent in the developed market economies and 2.7 percent in the developing market economies. Earlier USDA projections used higher rates for the developed countries and somewhat lower rates for the developing countries. At the world level, the 1.9-percent U.N. growth rate used in the model is somewhat lower than rates used in earlier publications of the USDA.

Income

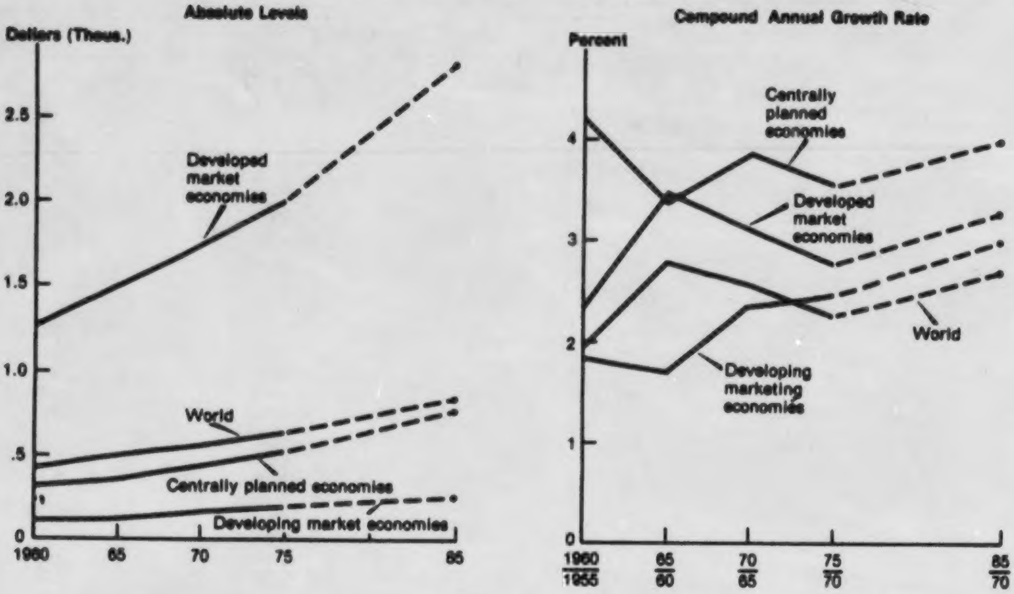
Income is another key variant in growth in demand for agricultural products. With given levels of population, prices, and other factors, the rate of increase in income largely determines the level, pattern, and variation in per capita consumption of agricultural products. While population may be the most important demand factor in developing countries, income is the most important factor in developed countries.

Where available, estimates of real per capita private consumption expenditures were used as income variables or demand shifters. For countries where these data were not available, either per capita gross domestic product or net material product was used (table 4 and fig. 4). In all cases, however, the implicit prices are those of 1970.

Income growth rates assumed in alternative I are the projected "trend" income values published in the Food and Agriculture Organization's 1974 Assessment of the World Food Situation, Present and Future. For the developing countries, these "trend" income projections were arbitrarily boosted by FAO to roughly 150 percent of the growth rates of the 1960's.

Table 4--World per capita private consumption expenditures and growth rates, average, 1969-71, and projected, 1985

Region	Private consumption expenditures per capita 1969-71 average	Private consumption expenditures per capita 1985 Alt. I projection	Compound annual growth rates
	- - U.S. dollars - -		Percent
Developed countries:	1,747	2,803	3.202
United States	3,026	4,660	2.921
Canada	2,237	3,490	3.009
EC-6	1,463	2,368	3.263
EC-3	1,374	1,846	1.989
Other Western Europe	1,008	1,858	4.161
Japan	966	2,142	5.452
Australia/New Zealand	1,596	2,455	2.913
South Africa	502	715	2.385
Centrally planned countries:	439	792	4.010
Eastern Europe	1,024	1,988	4.521
Soviet Union	1,202	2,422	4.782
China	113	161	2.388
Developing countries:	155	251	3.255
Middle America	449	696	2.964
Argentina	724	1,149	3.125
Brazil	268	633	5.893
Venezuela	535	796	2.687
Other South America	311	414	1.925
High-income North Africa & Middle East	261	614	5.864
Low-income North Africa & Middle East	188	306	3.301
East Africa	117	148	1.579
Central Africa	96	133	2.220
India	73	89	1.364
Other South Asia	95	101	.409
Thailand	130	248	4.392
Other Southeast Asia	83	99	1.182
	79	114	2.500
Indonesia	255	578	5.607
High-income East Asia	241	251	.271
Low-income East Asia			
Rest of world	181	232	1.669
World	560	834	2.691



World Per Capita Private Consumption Expenditures

Figure 4

Alternative I-A uses the same "trend" income assumptions of alternative I for the developed and centrally planned countries. For the developing countries, however, alternative I-A uses rates of increase close to those of the 1960's. These same slower growth income projections are also used for the developing countries in the low demand alternative III.

Alternative III assumes income growth rates to be one-third lower than in alternative I in all areas of the world, postulating that world inflation and economic stagnation would result in a worldwide low demand situation. For the developing countries, this corresponds roughly to the growth rates experienced during the 1960's. The high demand alternatives--II, IV, and IV-A--assume more rapid income growth rates; for the developed countries, the growth rates are roughly 20 percent higher than in alternative I, and for the developing countries, roughly 50 percent higher (table 5).

Prices

Demand, production, and trade quantities are projected simultaneously with major commodity prices in the grain-oilseed-livestock model. Commodity prices in each projection set differ, depending on the projected supply and demand balance. All prices are projected in real 1970 dollars because of recent high inflation rates and uncertainty as to the future purchasing power of money. Where utilized or implied, exogenous prices are also expressed in terms of 1970 dollars.

Table 5--World per capita private consumption expenditures and growth rates, by alternative, average, 1969-71, and projected, 1985

Region	1969-71 Base	1985 projection under alternative				
		I	I-A	II	III	IV & IV-A
	Real 1970 U.S. dollars					
World	560	834	814	915	730	915
Developed countries	1,747	2,803	2,803	3,075	2,553	3,075
Centrally planned countries	439	792	792	792	652	792
Developing countries	155	251	214	317	214	317
	Compound annual growth rates, percent 1/					
World	2.7	2.7	2.5	3.3	1.8	3.3
Developed countries	3.3	3.2	3.2	3.8	2.6	3.8
Centrally planned countries	3.6	4.0	4.0	4.0	2.7	4.0
Developing countries	2.0	3.3	2.2	4.9	2.2	4.9

1/ Growth rates under 1969/70-1971/72 base are computed from 1960 to 1970. Growth rates for 1985 are computed from base 1970.

Exchange Rates

For about four decades prior to August 1971, the United States maintained a stable dollar in foreign exchange markets. During that period, the U.S. dollar could be used as a numeraire for purposes of international currency value comparisons. This is no longer so confidently true. Since then, the dollar has been devalued twice and has been floating with respect to other currencies; gold has been removed from the central position in international monetary calculations and been replaced by the SDR--Special Drawing Rights--unit. For this reason, variables in the GOL model are expressed in local currency or in "dollar equivalent" terms. For the base period, 1970 exchange rates or average foreign currency conversion rates are used. For subsequent years foreign exchange conversion factors were adjusted to those shown in table 6. The use of these rates in the projected period is valid provided intervening exchange rate adjustments fully reflect changes in relative price levels in countries. The model does not project foreign exchange rates. Exchange rates depend upon many factors not included within the model. It is assumed that projected changes in region-to-region ratios of real prices would be reflected in changes in exchange rates.

Table 6--Currency and exchange rate specifications 1/

Region	Currency and exchange rates
Developed countries:	
United States	U.S. dollar
Canada	1 Canadian dollar = 1 dollar equivalent
European Community	1 unit of account = 1 dollar equivalent
Other Western Europe	Dollar equivalent
Japan	357.600 yen = 1 dollar equivalent
Australia/New Zealand	.897 Australian dollar = 1 dollar equivalent
South Africa	Dollar equivalent
Centrally planned countries:	
Eastern Europe	Dollar equivalent
Soviet Union	Dollar equivalent
People's Republic of China	Dollar equivalent
Developing countries:	
Argentina	3.75 new peso = 1 dollar equivalent
Others	Dollar equivalent

1/ Exchange rates as of July 1972. Dollar equivalent = 1 U.S. dollar.

Technology and Inputs

The GOL model treats technology and inputs, and their effect on productivity, as crucial supply shifters. Technological advances and improvements in both the quantity and quality of inputs used in the production of food affect not only immediate crop and livestock yields, but also the agricultural resource base. The continued evolution of technology along the lines of the recent past would be expected to expand the supply and improve the quality of resources to be used in food production. Perhaps the most obvious examples of this secondary effect of technology and inputs on the size and quality of the agricultural resource base are to be found in the impact of irrigation, the development and spread of pesticides and fertilizers, and the use of improved seeds and livestock strains.

The technology and inputs assumed in the GOL model either exist currently or are in the process of being developed. The availability of improved technology and the availability of inputs are consequently not assumed to be major impediments to future increases in food production. Accelerating the transfer of technology to the developing countries, adapting technology developed in the temperate countries to the needs of tropical countries, and encouraging adoption of technology and use of improved inputs by the small developing farmer, however, are likely to be significant bottlenecks. The GOL model assumes some advances are made in these areas. Full use of existing technology in the developing countries, however, would require a significant reorganization of the agriculture of much of the developing world.

The projections assume that the developed countries, and to a lesser extent the developing countries, will continue to take advantage of oncoming technological innovations and that limitation on the rate of adoption will depend mainly on the relative cost of inputs.

Several recent studies on land availability have concluded that at least twice as much of the world's land is suitable for crop production as is presently used. Nevertheless, there are serious regional problems resulting from a combination of population pressure on land and the difficulties of increasing agricultural production with prevailing technologies. As with other resources and economic opportunities, arable or potentially arable land is quite unequally distributed among the world's developing countries. This affects the options available to different groups and to different countries. A very large proportion of the world's people live in areas where possibilities for expanding the area cultivated are very limited. Bangladesh and Egypt, for example, must apply even more intensive, land-conserving methods of production to increase food output. The same is true, but with less extreme urgency, for Japan and Europe. Latin America and Africa have both intensive and extensive possibilities, as do Canada and the United States.

Except for Africa and Latin America, however, increases in land area will probably make progressively smaller proportionate contributions to future food supplies. The consensus of recent studies of world food production is that yield-increasing techniques will be the primary source of future growth in output, even in the developing countries (fig. 5).

Fertilizer is a key factor in yield increases, although it must be combined with other inputs, such as improved varieties of seeds and improved management practices, if it is to have its full potential impact on yields. Assumptions regarding fertilizer use are treated in greater detail in the discussion of alternatives IV and IV-A.

In addition to concern about the availability of land and fertilizer aroused by recent food shortages, some analysts question whether technological improvements will permit increases in crop yields in the future at the rates achieved in the

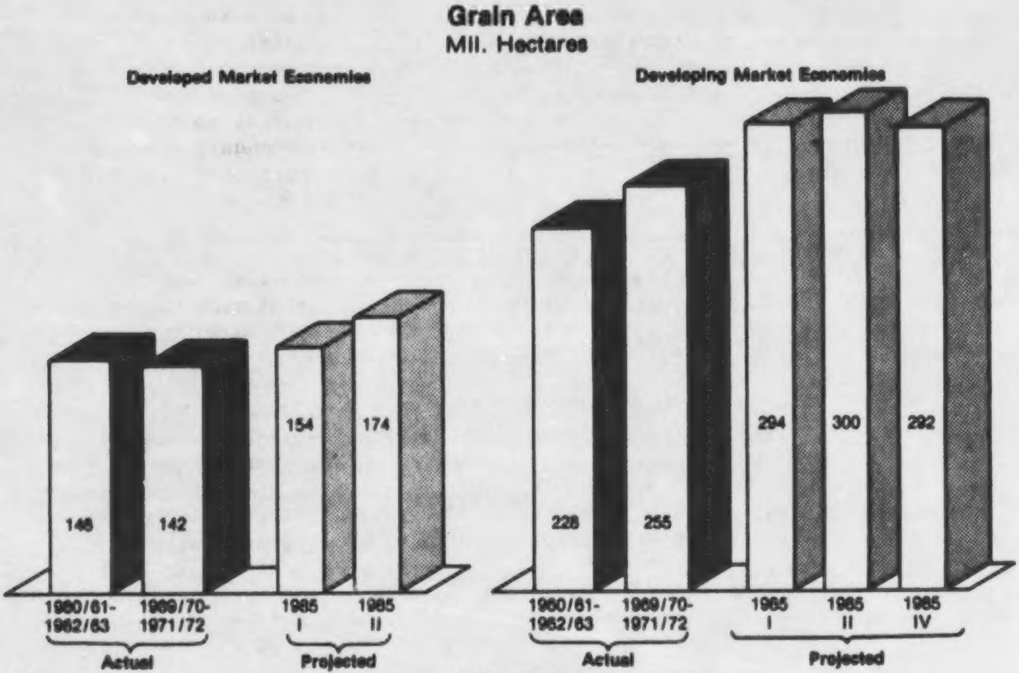


Figure 5

past. Attention has been focused on an apparent slowdown in the rate of production of some crops in some developed countries, and on the apparent loss of momentum of the Green Revolution in developing countries. The projections model assumes continued growth in grain yields in the developed countries but at rates below the highs of the 1960's. For the developing countries, the model assumes grain growth rates marginally above those of the 1960's.

Weather Variability and Stock Levels

Stock level assumptions are essentially part of broader production and trade policy assumptions. They are treated separately here, however, because of their importance in the current world food situation.

Assumptions about weather variability affect assumptions about stock levels, and vice versa. Assumptions about both affect the degree of price variability and, in turn, the projected levels of supply and trade. In general, less price variability occurs when growth in supply tends to be greater than growth in demand, resulting in a tendency to accumulate stock levels; the burdensome effect of the tendency to accumulate stocks, in turn, is mitigated by the frequency of droughts. Separate runs were made to study the relationship between short-term production shortfalls, longer term production levels, and stock levels.

Policy Assumptions

The production and trade policies of major food exporting and importing countries can have as much impact on future production and consumption patterns as can the interactions of economic variables. In the model, assumptions about government policies are included either explicitly in the mathematical formulations or implicitly in the coefficients used in the equations. For example, equations for the European Community (EC), provide explicitly for import levy variables. The equations for projecting grain area in the major grain exporting countries, on the other hand, have very responsive price coefficients to implicitly reflect the capability of government programs to readily adjust area to changed supply and demand situations.

Two important considerations of the policies of major grain exporting countries are basic to the assumptions of this study. The first is price maintenance at reasonable levels. The second is market share maintenance. It is not always possible to achieve both of these objectives at the same time. During periods of heavy world supplies, for example, prices cannot be maintained unless importers as well as exporters curtail production.

Price stability in periods of short supply can only be achieved if stocks are available. It is assumed that the major exporters will maintain sufficient stocks and implement production policies designed to maintain relative price stability in the longer run. In the shorter run, however, stocks would likely be kept below the levels needed to meet a series of successive production shortfalls similar to those of recent years. Implementation of such a policy could also be achieved through international cooperation. Thus, the meaning of the expression "continuation of policies" in the major exporting countries, such as the United States, is that they will follow production policies to keep the world grain supply in relative balance rather than permit continual appearance of sizable surpluses and deficits.

U.S. policies are important in establishing world price levels of many commodities. It is assumed that f.o.b. prices for these commodities in the United States and the appropriate c.i.f. prices abroad can be used as indicators of world supply and demand conditions.

An underlying feature of the import and domestic food production policies of major developed importing countries is that they attempt to at least maintain current self-sufficiency ratios. Japan would be a major exception, since her self-sufficiency ratio seems destined to decline. For all other major developed importing countries, it is assumed that recent food and fiber policies will be continued. Some modifications are provided for where it appeared that continuation of a particular policy would be untenable. Likewise, modifications, as well as the essentials of assumed food and fiber policies, can be different for the different alternatives.

The European Community is expected to continue its policy of enlargement. This means that the countries of the EC-3--the United Kingdom, Ireland, and Denmark--will continue through a transition period to become fully integrated economically with the EC-6 continental countries--France, Germany, Italy, Belgium, Luxembourg, and the Netherlands. It was assumed that the EC will continue to use variable levies and export subsidies to control the flow of imports and exports. High import levies, of course, limit trade, while low import levies increase trade. Levy and subsidy levels, however, differ under each alternative in order to be consistent with the food and fiber policy specified. It is also assumed that price policies of non-EC countries in Western Europe result in price levels similar to those in the Community. While Japan does not have specific import levies, its internal price and marketing structure is such that the effect is the same.

It is assumed that the longrun level of trade with the USSR, China, and Eastern Europe will be affected more by political factors than economic factors. The import policies of the centrally planned countries, particularly the USSR, will be influenced considerably by overall trade relations with the United States, as well as with other exporters. Actual trade levels will also depend on the extent to which the United States and other exporters are willing to absorb year-to-year variability in Soviet grain production.

Foot-and-mouth disease (hereafter called "aftosa") will continue to strongly influence livestock trade patterns. Since livestock in both Europe and South America already have aftosa, it was assumed that trade in fresh and frozen meat between these two continents will continue. Livestock in Oceania and the United States do not have aftosa, so it was assumed that these regions can export to the whole world, but will not import fresh or frozen meat from any of the aftosa areas. It was assumed that distances between Argentina and Europe are not too great to exclude trade in fresh beef on refrigerated ships.

Quotas on imports of beef into the United States were assumed to continue. If the projected imports obtained from the model are less than the quota, they become the imports.

It is also assumed that dairy product imports will continue to be limited by quotas in most countries. Butter imports into the United States are excluded and some growth in cheese imports is permitted if needed. Because of the continuation of health regulations and other policy and natural factors, fresh milk will not be traded. Primary adjustments in dairy markets between countries will take place in butter and cheese. It is assumed that prices of butter and cheese can be used as a barometer to measure degree of price pressures in the international dairy situation.

BASIS FOR EQUATIONS IN GOL MODEL

The "Analytical Framework" section of this report refers to the formal mathematical model used to project key economic variables in the grain, oilseed, and livestock sectors of the world's agricultural economy for some future period. The model's mathematical relationships are specified so as to capture the interplay of production, consumption, trade, and prices of grains, oilseeds, and livestock products. The equations appear in a separate volume reporting on the results of this research effort. The economic relationships underlying these equations are presented here.

The "Assumptions" section (see pp. 5 of the present report) discusses the usual assumptions concerning external variables, such as income and population, used to generate the economic variables being projected by a formal mathematical model. Specifying the formal nature of a mathematical model is very similar to specifying the income assumptions. For example, using linear relationships--as has been done--to represent the interplay of endogenous variables contained in the model does not give the same results as using nonlinear relationships.

The coefficients in the equations quantify the forces assumed to exist between the different variables in the grain-oilseed-livestock sector. However, the theoretical specification for a given variable is obscured by the units of measurement into which the full model is scaled. Therefore, to aid in interpreting the significance of the terms contained in the equations, tables in this section show the demand and supply elasticities, growth rates, input-output rates, and the proportionality factors (expressed in rates and percentages independent of the units of measurement) used in the model.

These tables take the following sequence: (1) Demand elasticities for meat, (2) demand elasticities for dairy products, (3) supply elasticities for meat, (4) supply elasticities for dairy products, (5) factors affecting use of grain as livestock feed, (6) factors affecting use of oilseed meal as livestock feed, (7) demand for grain in nonfeed use, and (8) area and yield elasticities for grain and oilseeds.

The model could not be a product of a direct statistical fit because of its size. The coefficients represented by the elasticities shown in the tables either were synthesized from statistical analyses or were the judgment of experts. Some of the more important work leading to these judgments will be discussed, as will the rationale for developing coefficients for those areas in which direct analyses were not available.

Consumption Levels, Income Response, and Economic Development

Substantial differences exist in consumption patterns among nations. During the 1969-71 base period, meat consumption varied from over 100 kilos in the United States and Australia to less than 10 kilos in some developing countries. Among the developed countries, per capita grain use was 825 kilos in the United States, 422 kilos in the EC-6, 408 in Other Western Europe, and 267 in Japan. In the developing world, per capita usage averaged only 178 kilos.

Knowledge of why these differences exist and future expectations of the differences are important in feed-livestock projections. This study hypothesizes that these differences will gradually diminish, with the low per capita use countries approaching levels of the high per capita use countries, but not necessarily reaching the same high levels or exhibiting identical consumption patterns.

In the present study, the strength of the income response coefficients, while depending on statistical results where feasible, is conditioned by the stage of economic development of a given country or region and by the likelihood of change in food consumption patterns.

Only a few studies have attempted to comprehensively study income response in a coordinated way. FAO has taken leadership in conducting cross section studies, using food surveys from different parts of the world (607) (610). FAO has used these results to build a set of estimated income elasticities for most countries of the world as a basis for its commodity projections work (603) (605). A few other studies involving mathematical models for trade in agricultural commodities also have been based on synthesized, integrated sets of income elasticities (1000) (1010) (1011) (1012) (1015) (1032) (1065) (1068). The income elasticities in the GOL model are also a synthesis of available information.

In general, at low levels of income, food consumption is expected to increase substantially with increases in income, but as income continues to rise the food consumption response weakens. At high levels of income, the added income expended for some food groups may taper off and even become negative. At low levels of income, diets are generally based on a few staple crops. Added income generally translates almost directly to consuming more of the same staples than to diversifying consumption with other products. But as income continues to rise, the income elasticity of grain for food begins to decline as diets become diversified from a cereals base to a wider grain-carbohydrate base and ultimately to a cereals-carbohydrate-livestock product base. A shift may also occur within the grains group, generally in the direction of wheat and rice at the expense of coarse grains. At appreciably higher levels of income, income elasticities for food grains fall off and eventually become negative as staples are replaced by a wide range of higher-price consumer preference products. This shifting pattern of consumption over time can also be viewed as part of a sequence of economic development from a single pastoral economy to a highly integrated, trade-oriented, commercial agricultural economy. An ERS study by Regier (158) demonstrated that income is a good indicator of the overall pattern of food consumption at different stages of economic development.

With respect to demand for grain for food, each stage of development can be observed throughout the world. Most of the developing countries--particularly South Asia, Central Africa, and the poorer parts of East Asia--fall into the category of relatively high, positive income elasticities. Results of studies on India (418), Pakistan (401), the Philippines (425), Bangladesh (401), and other countries (131) (407) (431), while varying somewhat as to statistical bases, indicate that the developing countries have positive income elasticities of demand ranging from .3 to .9 for wheat and rice, and from .2 to .5 for less preferred coarse grains. The income elasticities used in the GOL model for these developing countries fall within these ranges. Many countries in Latin America and the Middle East fall into a second category, characterized by moderately high income elasticities of demand of around .1 to around .3 for wheat, with coarse grains near the bottom of this range (402) (406) (410) (411) (413) (420) (426) (429). Many of the lower income developed countries and the developing exporting countries fall into a third category, categorized by very low, positive or possibly negative income elasticities in the range of +.1 to -.1 (127) (130) (137) (148) (412) (419) (421) (424). On the other hand, in a few of the developed countries, including the United States and some countries in Western Europe, the income elasticities for grains for food tend to be negative (149) (400) (404) (405) (414) (415) (422) (423) (427).

A number of factors, independent of income, can accelerate or decelerate changes in a country's elasticities. A country's present or traditional position as a surplus producer exporting grain or as a deficit producer depending on imported grain is the most obvious of the factors speeding up or slowing down income elasticity changes. Income elasticities of demand have moved further and faster along the hypothetical function described above in the case of the major exporters, particularly the United States, Canada, and Argentina, in earlier years and Thailand in recent years. The introduction of new grains or the introduction of new grain products can also keep elasticities higher than income levels alone would suggest. Such has been the case with wheat and wheat products in much of East Asia and to a lesser extent with coarse grain and coarse grain food products in parts of the United States and Western Europe.

In the GOL model, the income response to demand for grain for feed is considered differently for countries with fully developed livestock economies than it is for countries which are beginning to develop a livestock sector. In the former, income response coefficients appear explicitly in the meat and dairy product demand functions. Thus, in this case, consumption of feed grains and oilcake is a function of livestock output and the income effects are imputed through the feed input-livestock output ratios discussed below.

Two approaches are used for countries in which a livestock sector is not specified. If the livestock sector is not important, only a demand function for total coarse grains is specified. However, for areas where significant livestock growth is expected, a separate function for coarse grains used for feed is specified with higher income elasticities than those in the grain-for-food equation.

The same studies that provided income elasticities for grains were also useful for estimating income elasticities for meat and dairy products. In addition, econometric studies treating income, price, and other effects jointly were used and are identified below in relation to price elasticities. Income elasticities used in this study vary widely among regions, and within a region they vary among the different meat and dairy products. For the United States, there may still be room for further expansion of meat consumption, but the income effect is expected to taper off with continued income growth. Meat consumption is also at comparably high levels in Australia, a major exporter of beef and mutton, even though income levels are much lower than in the United States. Argentina, a major exporter of beef and mutton, also has high beef consumption levels, even though income levels are much lower than in the United States. For Argentina, the income coefficient is assumed to be .3. The income elasticities used for the EC-3, the EC-6, and Other Western Europe are higher than those used for the United States because of the lower consumption and income levels. Because meat consumption in Japan is still quite low in relation to the income level, the income elasticity exceeds unity. The study assumes that Japan will eventually attain the consumption levels of the United States and that national policy may be an important determinant as to their consumption levels.

Demand-Price Elasticities for Meat

The price-demand elasticities used in the GOL model rely heavily on the econometric studies cited below for the United States, Canada, the United Kingdom, France, Germany, Australia, and Argentina. The analyses in these studies, in general, are based on time series (historical) data, though cross section analysis is used for some countries (notably France, Japan, and the United Kingdom). Summaries of the elasticities obtained from these studies are summarized in Regier (157) and Mielke (147).

The Brandow study (1015) and a demand study by George and King (1032) present tables of direct and cross price elasticities for the mid-1950's and the mid-1960's, respectively. These interrelated price and income elasticities are subject to certain imposed consistency conditions of homogeneity and symmetry (see Frisch for this study). The direct and cross price elasticities shown in table 29 for the United States reflect these elasticities.

The demand-price elasticities synthesized for the EC-6 are based heavily on demand analysis in studies for Germany by Langen (1051), Stamer and Wolffram (1066), and Plate (1059); for France by CREDOC (404) and INSEE (1028); for both these countries by Kost (142); and for total meat demand for the EC-6 as a whole by Regier (155).

For several years, the United Kingdom has conducted annual household food surveys (1089) and has published demand elasticity measures as a result of this work. Time series analysis has also been done based on the surveys. Ferris, Josling, and others at Michigan State (301) also calculated demand elasticities for the United Kingdom, with somewhat different values for roughly the same time periods. Jones (422) developed a 39x39 matrix of demand elasticities for the United Kingdom. The elasticities used in the GOL model are closer to those reported in the U.K. study.

For Japan, three studies are important. Japan's Ministry of Agriculture has conducted demand analyses based on household budget surveys and has published demand results from both cross sectional and time series analyses (1045). The other two studies are by Filippello. The first study (1026) is an econometric analysis of the feed-livestock sector, while the second (127) uses the statistical results of the first study to determine a consistent matrix of elasticities.

Several country studies, cited elsewhere in this volume, have been useful in determining the demand elasticities for the other countries that have a modeled livestock sector. The more detailed work for the countries discussed above helps to fill the gaps in empirical work, particularly the cross substitution effects among the different meats. Thus, the analysis of demand elasticities for other Western Europe has been modeled after those determined for the EC-6. Canada has been patterned to some extent after the United States.

Australia-New Zealand, Argentina, Brazil, and Mexico-Central America are the other regions in the GOL model containing explicit livestock sectors. Demand-price (direct and cross) elasticities tend to be higher in the countries with the most developed livestock and marketing systems because of the availability of supply and choices open to the consumer.

Demand-Price Elasticities for Dairy Products

The dairy sector has been modeled only for the United States, Canada, the EC-3, the EC-6, Other Western Europe, Japan, and Australia-New Zealand (table 30). Many of the econometric studies cited above also contained price elasticity information for the dairy sector, as they dealt with the whole livestock sector. The Brandow (1015) and George and King (1032) studies estimated a demand matrix for a group of commodities. In addition to the studies cited for Germany, a study by Hesse (1038) was directly concerned with demand elasticities for milk and milk products.

Measuring consumers' price response to fluid milk and milk products has a very long history, mostly because the milk industry was one of the first to be regulated. Recent work by Halberg and Fallert (1034), Prat (1060), Wilson and Thompson (1087), and Boehm and Bobb (1013) confirms earlier studies that the demand for milk is

Table 29--Demand elasticities for meat

Item	Elasticity with respect to price of					Income elasticity
	Beef		Pork	Poultry	Mutton	
	Finished	Other				
United States:						
Beef, finished	-.7	.2	.1			.4
Beef, other	.4	-.8	.1	.1		.3
Pork	.4		-.8	.1		.1
Poultry	.3		.2	-1.0		.8
Mutton						
Canada:						
Beef		-.6	.3	.15		.7
Pork		.4	-.7	.15		.15
Poultry		.3	.2	-.8		.9
Mutton						
EC-6:						
Beef		-.7	.3	.1		.6
Pork		.5	-.8	.12		.5
Poultry		.38	.5	-1.07		1.0
Mutton		.15	.15		-.25	0
EC-3:						
Beef		-.6	.2	.08	-.2	.7
Pork		.18	-.8	.2	.17	.45
Poultry		.3	.3	-.6		1.0
Mutton		.1	.1	.1	-.1	0
Other Western Europe:						
Beef		-.6	.2	.1		.7
Pork		.2	-.7	.2		.6
Poultry		.1	.2	-.8		.9
Mutton		.15	.15		-.25	0
Japan:						
Beef		-1.2	.26	.35		1.2
Pork		.20	-.90	.11		.9
Poultry		.50	.17	-1.10		.6
Mutton		-.4	.2	.3	-.4	.5
Oceania:						
Beef		-.5			.2	0
Pork		.2	-.4			.1
Poultry						
Mutton		.4			-.8	0
Mexico & Central America:						
Beef		-.4	.1			.7
Pork		.1	-.3			.6
Poultry						
Mutton						
Argentina:						
Beef		-.4				.3
Pork		.2	-.4			0
Poultry						
Mutton		.2			-.4	0
Brazil:						
Beef		-.6	.3			.4
Pork		.2	-.6			.4
Poultry						
Mutton						

Table 30--Demand elasticities for dairy products

Item	Elasticity with respect to price of			Income elasticity
	Milk	Butter	Cheese	
United States:				
Milk, fluid	-.2			-.1
Butter		-.7		
Cheese			-.5	.5
Canada:				
Milk, fluid	-.2			-.1
Butter		-.7		-.3
Cheese			-.5	.6
EC-6:				
Milk, fluid	-.25			.2
Butter		-.7		.2
Cheese			-.6	.5
EC-3:				
Milk, fluid	-.15			.2
Butter		-.5		.2
Cheese			-.6	.3
Other Western Europe:				
Milk, fluid	-.2			.3
Butter		-.5		.3
Cheese			-.6	.6
Japan:				
Milk, fluid	-.7			.95
Butter		-.7		1.0
Cheese			-1.69	1.25
Oceania:				
Milk, fluid	-.2			.1
Butter		-.4		-.1
Cheese			-.3	.5

inelastic. There appears to be a general agreement that the demand-price elasticity is in the neighborhood of -.2 for fluid milk. The values used in the GOL model for all areas except Japan approximate the historical values (table 30). A considerably higher elasticity is used for Japan because of the still low per capita consumption. The demand-price elasticity for cheese ranges between -.5 and -.6 and much higher in Japan for the same reasons cited above. The price elasticity for butter varies from -.4 to -.7. Higher elasticites for butter were used for regions where margarine is substitutable because of availability, as in the United States.

Supply-Price Elasticities for Livestock, Meat, and Dairy Products

A complete study of the supply side of the livestock sector would include the study of factors affecting livestock numbers, slaughter numbers, slaughter weight or yield, and production. It would include a study of cycles, mostly for beef cattle and to a lesser extent for hogs. However, the present study projects only equilibrium values at some future time period and abstracts from cycles and explicit projections of the herd. As presently modeled, supply relations in the GOL livestock sector are based on direct and cross price elasticities for livestock commodities or products, and on a set of supply shift variables which reflect long-term growth factors.

Considerable work on supply response has been done on products competing for some fixed bundle of resources. Most of these studies have been confined to activity analysis. Supply response coefficients derived from such programming models, while very informative, seldom can be used directly in a projections model such as GOL, which essentially is a behavioral model. Results from regression type analyses are more compatible for developing direct and cross supply response coefficients.

While many regression studies appear to report statistically significant results for direct supply-price elasticities, most studies have difficulty in determining the cross price effects. For this reason, the sets of direct and cross supply-price elasticities used for many of the model's regions are based on judgment. Some of these coefficients are tentative and will be improved over time.

Results obtained from regression analyses by Johnson (139) and Regier (155) for the meat sector, and by Halberg and Fallert (1034) for the dairy sector were helpful for assessing the supply response for the United States and the European Community. ERS also conducted feed-livestock studies for Canada (148), Argentina (1037), Australia (130), and New Zealand (105) in the early 1970's that concentrated on the supply side (tables 31-32).

Recent results indicate that the supply response of milk production to milk price still remains relatively low—the supply-price elasticity is in the neighborhood of .2 (see Halberg and Falbert (1034). The GOL model used an elasticity of .15. As expected, the studies of the meat sector also showed that the price-supply response for beef was the lowest, for pork more responsive, and for poultry the most responsive. Major adjustments in beef cattle operations take several years from the time of initial decision compared with major adjustments that can take place within a single year for a poultry operation. The price-supply response appears to be between .3 and .4 for beef, around .6 to .7 for pork, and somewhat higher for poultry.

Feed Demand Equations

The crop and livestock sectors of the GOL model are linked via two sets of feed demand equations—one for grain and one for oilseed meal. Each equation has three components: (1) input-output coefficients defined in physical terms which relate quantities of grain or meal used as feed to quantities of livestock products produced, (2) direct and cross price elasticities which affect feeding rates with changing prices, and (3) long-term growth factors reflecting changes in basic feeding patterns.

Table 31--Supply elasticities for meat

Item	Elasticity with respect to price of						
	Beef	Pork	Poultry	Mutton	Milk	Corn	Oilcake
United States:							
Beef	.3					-.2	-.05
Pork		.5				-.4	-.1
Poultry			.9			-.6	-.2
Mutton							
Canada:							
Beef	.4	-.1				-.2	-.05
Pork	-.2	.6	-.2			-.4	-.1
Poultry	-.1	-.2	.7			-.4	-.2
Mutton							
EC-6:							
Beef	.4	-.15			.15	-.2	-.1
Pork	-.3	.7	-.3			-.4	-.2
Poultry	-.2	-.2	.7			-.4	-.3
Mutton	-.15			.3	.15	-.15	
EC-3:							
Beef	.4	-.15			.15	-.2	-.1
Pork	-.15	.7	-.15			-.4	-.2
Poultry	-.2	-.2	.7			-.4	-.3
Mutton	-.15			.3	.15	-.15	
Other Western Europe:							
Beef	.4	-.15			.15	-.2	-.1
Pork	-.2	.5	-.2			-.3	-.15
Poultry	-.2	-.2	.6			-.3	-.25
Mutton	-.15			.3	.15	-.15	
Japan:							
Beef	.5	-.1	-.1	.2		-.3	
Pork		.7	-.2		-.15	-.4	-.2
Poultry		-.2	.7			-.4	-.3
Mutton							
Oceania:							
Beef	.4			-.1			
Pork	-.1	.3				-.2	
Poultry							
Mutton				.2			
Mexico & Central America							
Beef	.4	-.1					
Pork	-.1	.3				-.4	
Poultry							
Mutton							
Argentina:							
Beef	.5						
Pork	-.1	.3				-.2	
Poultry							
Mutton				.2			
Brazil:							
Beef	.5						
Pork	-.1	.4				-.3	-.15
Poultry							
Mutton							

Table 32--Supply elasticities for dairy products

Item	Elasticity with respect to price					Elasticity of joint output with beef
	Milk	Butter	Cheese	Corn	Oilcake	
United States:						
Milk, total	.4			-.3	-.2	
Cheese		-.6	.6			
Canada:						
Milk, total	.30			-.40	-.20	
Cheese		-.6	.6			
EC-6:						
Milk, total	.35			-.5	-.3	.5
Cheese			.4			
EC-3:						
Milk, total	.35			-.2	-.1	
Cheese			.4			
Other Western Europe:						
Milk, total	.3			-.35	-.1	
Cheese			.5			
Japan:						
Milk, total	.8			-.25	-.3	
Cheese						
Oceania:						
Milk, total	.4			-.2		
Cheese		-1.0	1.0			

The input-output coefficients computed for the 1969-71 base period reflect full utilization and distribution of grains and oilseed meals among livestock products. Studies by Allen (200), the National Academy of Sciences (500-504), OECD (803-804), and Weightman (505-509) on feed use provided bases for the budgeting process. The input-output coefficients are shown in table 33 for grain and in table 34 for oilseed meal.

Results from regression analyses for the United States by Ahalt and Egbert (103), and Womack (1088) and for the EC-6 by Regier (157) form the basis for estimating price coefficients used in the GOL model. Results of the U.S. and EC-6 studies are similar. For example, in both cases, the demand elasticity for feed grain with respect to grain prices is around -0.4 to -0.5 and about 0.1 with respect to meal prices. Because oilcake forms a much smaller proportion of total feed than grains, the price elasticities for meal with respect to prices of grain and oilcake are much higher.

Expected growth in input-output rates not explicitly accounted for by the first two components discussed above are introduced as an explicit growth factor. For those regions in which feed demand equations are not directly related to livestock production, an income variable is used to reflect growth in demand for livestock products. The income elasticities resemble those associated with direct demand for meat.

Table 33--Factors affecting use of grain as livestock feed

Explanatory factors	United States	Canada	EC-6	EC-3	Other Western Europe	Japan
	Kg. grain use per kg. product					
Input-output rates:						
Beef, finished	5.74					
Beef, other	2.02	4.60	1.30	2.27	2.46	2.33
Pork	6.43	6.50	3.60	4.22	4.60	5.09
Poultry	2.76	2.90	2.70	2.70	2.80	2.40
Lamb and mutton	(1.86)		.25	.25		
Milk	.33	.33	.125	.21	.28	.20
Eggs	2.91	3.10	3.10	3.10		2.40
	Percentage change in grain use per unit percent price change					
Price elasticities:						
Beef, finished	.22					
Beef, other	.03	.25				
Pork	.25	.25	.50	.50	.40	.50
Corn	-.40	-.40	-.50	-.50	-.50	-.60
Oilseed cake	.10	.10	.10	.10	.10	.10
	Percentage change in grain use per unit percent income change					
Income elasticity:						
Income per capita						

Explanatory factors	Australia, New Zealand	South Africa	Eastern Europe	Soviet Union	China	Mexico Central America
	Kg. grain use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other	.30		2.80	3.00		.30
Pork	3.40		4.60	5.00	2.0	3.00
Poultry	3.00		3.00	3.50	1.0	
Lamb and mutton						
Milk	.12		.30	.30		
Eggs	3.00		(3.10)	3.50		
	Percentage change in grain use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						.20
Pork	.30		.25			-.20
Corn	-.30	-.30	-.25			
Oilseed cake						
	Percentage change in grain use per unit percent income change					
Income elasticity:						
Income per capita		.25				.10

Continued--

Table 33--Factors affecting use of grain as livestock feed --Continued

Explanatory factors	Argentina	Brazil	Venezuela	Other South America	N. Africa-Middle East high	N. Africa-Middle East low
	Kg. grain use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other	.50	1.50				
Pork	3.60	3.60				
Poultry						
Lamb and mutton						
Milk						
Eggs						
	Percentage change in grain use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						
Pork	.30	.30				
Corn	-.30	-.40	-.30	-.40	-.30	-.15
Oilseed cake		.10				
	Percentage change in grain use per unit percent income change					
Income elasticity:						
Income per capita	.20	.20	.20	.20	.30	.10

Explanatory factors	East Africa	Central Africa	India	Other South Asia	Thailand	Other Southeast Asia
	Kg. grain use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other						
Pork						
Poultry						
Lamb and mutton						
Milk			(.05)			
Eggs						
	Percentage change in grain use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						
Pork						
Corn	-.30		-.40	-.20	-.1	-.3
Oilseed cake						
	Percentage change in grain use per unit percent income change					
Income elasticity:						
Income per capita	.20	.15	.40	.20	.1	.2
	Grain use as a proportion of commodity supply					
Market shares:						
Commodity supply feed grain			.15			

Continued--

Table 33--Factors affecting use of grain as livestock feed --Continued

Explanatory factors	Indonesia	East Asia high	East Asia low	Rest of world
	Kg. grain use per kg. product			
Input-output rates:				
Beef, finished				
Beef, other				
Pork				
Poultry				
Lamb and mutton				
Milk				
Eggs				
	Percentage change in grain use per unit percent price change			
Price elasticities:				
Beef, finished				
Beef, other				
Pork				
Corn	-.30	-.50	-.30	
Oilseed cake				
	Percentage change in grain use per unit percent income change			
Income elasticity:				
Income per capita	.30	.40	.20	
Market shares:				
Commodity supply feed grain				

Table 34--Factors affecting use of oilseed meal as livestock feed

Explanatory factors	United States	Canada	EC-6	EC-3	Other Western Europe	Japan
	Kg. oilmeal use per kg. product					
Input-output rates:						
Beef, finished	.25					
Beef, other	.44	.10	.16	.12	.15	.50
Pork	.45	.35	.67	.55	.65	1.40
Poultry	.87	.60	1.18	1.05	1.16	1.20
Lamb and mutton	1.72					
Milk	.033	.03	.033	.025	.028	.08
Eggs	.47	.35	.71	.60		.70
	Percentage change in oilmeal use per unit percent price change					
Price elasticities:						
Beef, finished	-.10					
Beef, other	.23					
Pork	.27	.90	1.20	1.80	1.00	1.20
Corn	1.00	2.50	.90	1.00	1.20	1.50
Oilseed cake	-.53	-.98	-.25	-.37	-.20	-.30
	Percentage change in oilmeal use per unit percent income change					
Income elasticity:						
Income per capita						

Explanatory factors	Australia New Zealand	South Africa	Eastern Europe	Soviet Union	China	Mexico Central America
	Kg. oilmeal use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other						
Pork			.40	.40	.40	
Poultry			.50	.50	.50	
Lamb and mutton						
Milk			.01	.01		
Eggs			.13	.40		
	Percentage change in oilmeal use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						
Pork						
Corn						.20
Oilseed cake	-.30					-.20
	Percentage change in oilmeal use per unit percent income change					
Income elasticity:						
Income per capita.						
	Oilmeal use as a proportion of commodity demand					
Market shares:						
Commodity demand feed grain		.19				.32

Continued--

Table 34--Factors affecting use of oilseed meal as livestock feed--Continued

Explanatory factors	Argentina	Brazil	Venezuela	Other South America	N. Africa-Middle East High	N. Africa-Middle East Low
	Kg. oilmeal use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other						
Pork						
Poultry						
Lamb and mutton						
Milk						
Eggs						
	Percentage change in oilmeal use per unit percent price change					
Price elasticites:						
Beef, finished						
Beef, other						
Pork						
Corn						
Oilseed cake	-.50	-.40		-.30		
	Percentage change in oilmeal use per unit percent income change					
Income elasticity:						
Income per capita						
	oilmeal use as a proportion of commodity supply					
Market shares:						
Commodity demand feed grain	.047	.064		.21	.30	

Explanatory factors	East Africa	Central Africa	India	Other South Asia	Thailand	Other Southeast Asia
	Kg. oilmeal use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other						
Pork						
Poultry						
Lamb and mutton						
Milk			(.10)			
Eggs						
	Percentage change in oilmeal use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						
Pork						
Corn						
Oilseed cake			-.20			
	Percentage change in oilmeal use per unit percent income change					
Income elasticity:						
Income per capita			.10			

Continued--

Table 34--Factors affecting use of oilseed meal as livestock feed--Continued

Explanatory factors	Indonesia	East Asia High	East Asia Low	Rest of World
	Kg. oilmeal use per kg. product			
Input-output rates:				
Beef, finished				
Beef, other				
Pork				
Poultry				
Lamb and mutton				
Milk				
Eggs				
	Percentage change in oilmealuse per unit percent price change			
Price elasticities:				
Beef, finished				
Beef, other				
Pork				
Corn				
Oilseed cake	-.20	-.30		
	Percentage change in oilmeal use per unit percent income change			
Income elasticity:				
Income per capita	.30	.30		

Demand-Price Elasticities for Grain for Food

Two general tendencies can be identified concerning the demand-price elasticities for grain consumed directly for food. The first is that demand price elasticities tend to be higher in low income countries having primarily cereal diets than in high income countries with more diversified diets. The second tendency is that the demand price elasticity for grain consumed as food is lower than the demand elasticity for grain as feed, both within single countries and across country groupings. These inferences can be drawn from summaries of demand elasticities presented in Rojko, Urban, and Naive (167), Hutchinson (136), Keefer (140), and in a cross section world study by Regier (154) (table 35).

The demand response to price changes in the developing countries is appreciably stronger than in the developed countries. This results at least in part because the budget effect of comparable price changes is greater when incomes are low and a large proportion of the budget is spent on food. Furthermore, in some developing countries, grain accounts for as much as 60-70 percent of total food expenditures. Consequently, the highest price elasticities, or the strongest responses to price changes, would be found in the lower income, less developed, importing countries consuming the bulk of their grain directly as food rather than indirectly as livestock products. South Asia and parts of East Asia fall into this category. In contrast, the more food demand-price inelastic regions--that is, the least food demand-price responsive of the regions treated in the GOL model--include the highest income, grain-feeding, developed exporting countries such as the United States, Canada, and Oceania.

Supply Elasticities for Grains and Oilseeds

The GOL model's grain production functions are basically generated through three sets of equations. The first set is an equation for each region that generates the total area used in grains and oilseeds. The second set of equations generates area used specifically in the production of wheat, coarse grains, rice, and oilseeds. The third set of equations introduces a yield variable to generate production for wheat, coarse grains, rice, and oilseeds. The area equations for the individual crops are constrained by the total area projected from the first set of equations. Area assigned to the individual crops depends on relative prices of these crops and basic long-term shifts that are projected to occur among the crops. The production equation basically reflects both area and yield effects in the projection period. 5/ This is accomplished by incorporating the projected area as a variable in the production equation for combination with yield variables. The production equations also contain variables to reflect changes in production due to yield. These yield factors include relative prices, some trend values reflecting yield growth changes due to changes in technology, and a shift variable to reflect different levels of input activity. For the developed world, input activity is represented by a cost index variable. For the developing world, a physical input use bundle is used as a variable to indicate input intensity. Specifically, different levels of production may be generated by varying this input bundle of resources (table 36).

5/ Ideally, area and yield equations should be generated separately and the estimates from them multiplied to obtain total production. Because our model does not allow for nonlinear relationships, it was essential to achieve equivalent results through use of additive functions.

Table 35--Factors affecting nonfeed use of grains and oilseeds 1/

Item	Elasticity with respect to price of: Wheat	Rice	Coarse grains	Income elasticity	Annual demand trend 2/: Quantity	Percent of 1969-71 base
					1,000 metric tons	Percent
United States:						
Wheat	-.2					
Rice		-.2		.2		
Coarse grains			-.2			
Oilseeds						
Canada:						
Wheat	-.05		.03	-.25		
Rice		-.3		.15		
Coarse grains	.05		-.10	-.3		
Oilseeds						
EC-6:						
Wheat	-.2			-.1		
Rice		-.3		.2		
coarse grains			-.2	.1		
Oilseeds						
EC-3:						
Wheat	-.1			-.03		
Rice		-.3		.2		
Coarse grains			-.15	.05		
Oilseeds						
Other Western Europe:						
Wheat	-.25		.1	-.05		
Rice	.2	-.3		.2		
Coarse grains	.15		-.35	.10		
Oilseeds						
Japan:						
Wheat	-.45	.2		.2	50	.99
Rice	.10	-.15		-.20		
Coarse grains			-.25	.2		
Oilseeds 3/			-.1	.8		
Australia & New Zealand:						
Wheat	-.15			-.25		
Rice		-.1		.1		
Coarse grains			-.15	-.2		
Oilseeds						
South Africa:						
Wheat	-.15		.10	.1		
Rice	.15	(-.3)		.1		
Coarse grains	.03		-.08	-.05		
Oilseeds						
Mexico & Central America:						
Wheat	-.35	.10	.15	.35		
Rice	.2	-.4	.05	.35		
Coarse grains	.05		-.2	.1		
Oilseeds						
Argentina:						
Wheat	-.1		.05	-.1		
Rice	.05	-.2		.15		
Coarse grains	.05		-.1	-.25		
Oilseeds						

See footnotes at end of table.

Continued--

Table 35 --Factors affecting nonfeed use of grains and oilseeds 1/ --Continued

Item	Elasticity with respect to price of			Income elasticity	Annual demand trend 2/	
	Wheat	Rice	Coarse grains		Quantity	Percent of 1969-71 base
					1,000 metric tons	Percent
Brazil:						
Wheat	-.25	.10	.10	.25		
Rice	.2	-.2	.02	.15		
Coarse grains	.05	.05	-.15	.1		
Oilseeds						
Venezuela:						
Wheat	-.3	.1	.1	.35		
Rice	.2	-.1		.15		
Coarse grains	.15		-.25	.15		
Oilseeds						
Other South America:						
Wheat	-.25	.1	.15	.3		
Rice	.2	-.2		.35		
Coarse grains	.2		-.35	.15		
Oilseeds						
North Africa/Middle East--High:						
Wheat	-.25	.03	.02	.25		
Rice	.18	-.3	.04	.3		
Coarse grains	.2	.1	-.2	.15		
Oilseeds						
North Africa/Middle East--Low:						
Wheat	-.35	.15	.10	.05		
Rice	.15	-.25	.10	.2		
Coarse grains	.15	.1	-.25	.1		
Oilseeds						
East Africa:						
Wheat	-.3	.05	.15	.35	20	3.54
Rice	.1	-.25	.15	.3		
Coarse grains	.02	.01	-.05	.1		
Oilseeds						
Central Africa:						
Wheat						
Rice		-.2		.1		
Coarse grains						
Oilseeds						
India:						
Wheat	-.4	.15	.1	.7		
Rice	.1	-.4	.01	.7		
Coarse grains	.1	.10	-.35	.2	-210	-.86
Oilseeds						
Other South Asia:						
Wheat	-.4	.25	.01	.4		
Rice	.2	-.30	.03	.4		
Coarse grains	.15	.2	-.20	.2		
Oilseeds						
Thailand:						
Wheat	-.05	.2		.2		
Rice		-.05	.01	.1		
Coarse grains		.2	-.1	.2		
Oilseeds						

See footnotes at end of table.

Continued--

Table 35--Factors affecting nonfeed use of grains and oilseeds 1/--Continued

Item	Elasticity with respect to price of: Wheat	Rice	Coarse grains	Income elasticity	Annual demand trend 2/: Quantity	Percent of 1969-71 base
					1,000 metric tons	Percent
Other Southeast Asia:						
Wheat	-.1	.15		.2		
Rice	.01	-.05		.1		
Coarse grains				.15		
Oilseeds						
Indonesia:						
Wheat	-.6	1.0	.4	.55	5	.94
Rice	.04	-.25	.03	.45		
Coarse grains	.03	.3	-.3	.3	50	2.09
Oilseeds						
East Asia--High:						
Wheat	-.3	.2	.04	.10		
Rice	.15	-.3	.05	.05		
Coarse grains	.1	.2	-.3	.05		
Oilseeds						
East Asia--Low:						
Wheat	(-.35)	(.15)	.2	.35		
Rice	(.05)	(-.22)	.05	.2		
Coarse grains	(.05)	(.15)	-.25	.2		
Oilseeds						

1/ Including food use of soybeans in the case of Japan. The use of parentheses in the table indicates trade prices; the absence of parentheses indicates demand prices.

2/ Trend in demand independent of any price effect.

3/ The coefficient shown in the coarse grain column is an elasticity with respect to the price of soybeans.

Table 36--Factors affecting the supply of grains and oilseeds 1/

Item	Area elasticity with respect to price of				Yield elasticity with respect to price of			
	Wheat	Rice	Coarse grains	Oilseeds	Wheat	Rice	Coarse grains	Oilseeds
United States:								
Wheat	(2.5)		(-1.84)	(-.69)	(.05)			
Rice		(.8)				(.10)		
Coarse grains	(-.83)		(2.3)	(-1.00)			(.10)	
Oilseeds	(-.78)		(-3.60)	(3.25)				(.02)
Canada:								
Wheat	.5		-.40	-.15	.15			
Rice								
Coarse grains	-.55		.55	-.15			.15	
Oilseeds	-.16		-.24	1.0				.20
EC-6:								
Wheat	.7		-.70		.25			
Rice		.20				.20		
Coarse grains	-.61		.61				.30	
Oilseeds								
EC-3:								
Wheat	.65		-.55		.2			
Rice								
Coarse grains	-.161		.147				.2	
Oilseeds								.02
Other Western Europe:								
Wheat	.25		-.25		.25			
Rice		.15				.15		
Coarse grains	-.185		.185	.10			.30	
Oilseeds				.10				.10
Japan:								
Wheat					.30			
Rice		.012		-.02		.15		
Coarse grains							.25	
Oilseeds		-.2		.28				.15
Australia & New Zealand:								
Wheat	.4		-.35		.15			
Rice		.10				.1		
Coarse grains	-.75		.66				.15	
Oilseeds				.30				.15
South Africa:								
Wheat	.30				.25			
Rice								
Coarse grains			(.30)	(-.3)			(.30)	
Oilseeds								(.10)
Mexico & Central America								
Wheat	.45		-.25	-.07	.20			
Rice		.15				.10		
Coarse grains	-.02		.04	-.02			.07	
Oilseeds	-.21		-.46	.50				.05
Argentina:								
Wheat	.4		-.31		.10			
Rice		.25				.30		
Coarse grains	-.21		.3	-.15			.15	
Oilseeds	-.15		-.30	.45				.10

See footnote at end of table.

Continued--

Table 36--Factors affecting the supply of grains and oilseeds 1/ --Continued

Item	Area elasticity with respect to price of				Yield elasticity with respect to price of			
	Wheat	Rice	Coarse grains	Oilseeds	Wheat	Rice	Coarse grains	Oilseeds
Brazil:								
Wheat	.7		-.70		.05			
Rice		.2	-.10			.10		
Coarse grains	-.12		.3	-.20			.08	
Oilseeds			-1.10	1.6				.05
Venezuela:								
Wheat								
Rice		.50	-.756			.15		
Coarse grains		-.10	.15				.15	
Oilseeds								
Other South America:								
Wheat	.2		-.05		.10			
Rice		.15	.07			.15		
Coarse grains	-.10		.05	-.03			.05	
Oilseeds			-.08	.20				.10
North Africa/Middle East--High:								
Wheat	.1	-.03	-.03		.05			
Rice	-.20	.50				.15		
Coarse grains	-.25		.09				.05	
Oilseeds								
North Africa/Middle East--Low:								
Wheat	.15		-.06		.10			
Rice	-.02	(.30)				(.20)		
Coarse grains	-.20		.07				.05	
Oilseeds								
East Africa:								
Wheat	.10				.05			
Rice		.20				.15		
Coarse grains			.15				.10	
Oilseeds								
Central Africa								
Wheat								
Rice						.20		
Coarse grains								
Oilseeds								
India:								
Wheat	.30	-.20	-.12		.08			
Rice	-.05	.25	-.10			.07		
Coarse grains	-.05	-.10	.17	-.062			.04	
Oilseeds	-.055	-.09	-.12	.20				.15
Other South Asia:								
Wheat	.1	-.05	-.02		.05			
Rice	-.015	.025				.03		
Coarse grains	-.25		.07				.02	
Oilseeds								
Thailand:								
Wheat								
Rice		.05				.10		
Coarse grains			.1				.10	
Oilseeds								

See footnote at end of table.

Continued--

Table 36--Factors affecting the supply of grains and oilseeds 1/ --Continued

Item	Area elasticity with respect to price of				Yield elasticity with respect to price of			
	Wheat	Rice	Coarse grains	Oilseeds	Wheat	Rice	Coarse grains	Oilseeds
Other Southeast Asia:								
Wheat								
Rice		.10				.10		
Coarse grains							(.20)	
Oilseeds								
Indonesia:								
Wheat								
Rice		.2	-.03			.10		
Coarse grains			.14	-.10			.05	
Oilseeds			-.15	.30				.02
East Asia--High								
Wheat	.25	-.20			.20			
Rice	-.02	.19	-.10	-.01		.15		
Coarse grains		-.25	.3	-.10			.20	
Oilseeds		-.26	-.19	.25				.02
East Asia--Low								
Wheat.								
Rice		.06	-.06			.08		
Coarse grains		-.10	.1				.05	
Oilseeds								(.03)

1/ The use of parentheses in the table indicates trade prices; the absence of parentheses indicates supply prices.

The elasticities used in the equations are shown in table 36 and were derived from published and unpublished USDA studies or from studies outside the USDA. Only three studies are cited here because each contains summaries of supply response studies. These studies are by Rojko, Urban, and Naive (167), FAO (607), and Behrman (1008).

While the assumption that production in the developed countries is price responsive is generally unchallenged, some question might be raised as to the applicability of price analysis in the study of developing countries. The GOL model assumes that farmers in the developing countries respond much the same as do farmers in the developed countries--positively to price increases and negatively to price decreases. However, studies indicate a weaker response in the developing countries when the total agricultural sector is analysed rather than the smaller, commercialized market subsector. This dampened responsiveness is largely due to physical and institutional constraints on production as well as to constraints on the distribution of surplus production in isolated, near-subsistence regions.

The supply elasticities used in the GOL model for both the developed and developing countries reflect the full effect of a price change on production adjustment over a number of successive years. In short they might be considered long-term elasticities.

Area Elasticities

Land use patterns are affected by changes in multiple-cropping cultivation or previously uncultivated area, or through displacement of other crops. A number of other physical factors affect a region's area-price responsiveness. Climate and soil constraints as well as limited supplies of arable land or multiple-cropping potential tend to dampen area responsiveness. Nonphysical factors such as rural institutions, agricultural infrastructure, and the degree to which an agricultural sector has been commercialized also affect a producer's responsiveness. While the above factors probably apply more to the developing countries, the overriding factor in the developed countries may be agricultural programs, particularly in periods of heavy supply.

Extreme caution should be used in interpreting area elasticities presented in table 36. These elasticities represent both the usual or traditional individual producer response to economic stimuli and the aggregate response to government programs. In addition, the area elasticities shown include the cumulative effects of both the total area and individual crop equations.

Under alternative I, very high area-price elasticities are used for the major grain exporters to reflect government programs that result in lower acreages when supply appears to be growing faster than demand. On the other hand, under alternative II, the area-price elasticities for these exporters are considerably reduced as pressure is applied against the base of readily available land and expansion of area requires considerably higher costs. These area coefficients reflect government programs when land is not fully utilized but approach traditional producer's price response as prices go above support levels.

The somewhat higher than expected area elasticities for the EC-6 and EC-3 of .6 to .7 reflect the ease of substitution of one grain crop for another as relative prices change. However, the total area response of .1 is quite low, indicating that there is little room for expansion of total area in the EC-6 or EC-3.

Lower elasticities were used for the other resource-tight developed importing countries (for instance, Japan) and for the developing countries with large subsistence sectors or large reserves of arable land but fixed, traditional land usage patterns (such as Central and East Africa).

The lowest direct area elasticities—+.05 to +.10—were used for land-short, largely subsistence farming regions, such as India and Other South Asia. Indirect or cross elasticities were found to be more closely related to the degree of commercialization and the number of competing crops. The more subsistence-oriented farmers were found to be less able or willing to move out of a particular staple grain crop, to break with traditional patterns of cultivation, or to change crop rotation.

Yield-Price Elasticities

Expanding production in the decades ahead is likely to depend on growth in yields rather than growth in area. Yield responses to price changes within a single decade are likely to be largely related to increased use of fertilizer. Increases in yield within a single decade from increases in other yield-augmenting inputs such as an increase in irrigation facilities will be limited. Changes in yield in response to price changes over the longer term of several decades depends on the degree that yield-augmenting inputs can be changed. Costly, long-term investments in agricultural infrastructure necessary if high productivity inputs are to be used effectively are not easily speeded up or slowed down in response to price changes. Also, improvements in technology--perhaps the single most important source of growth in yields--often take place irrespective of price changes: the effect of these technological improvements on reducing costs may actually raise net farm returns even as product prices are falling.

The yield-price elasticities used in the GOL model reflect increased use of fertilizer, with limited changes in the total bundle of other inputs. Thus, yield elasticities appear to be positively correlated with existing levels of yields and past yield growth rates. The highest elasticities were found in those regions with grain yields in excess of 2.5 tons per hectare and with trend growth in yield in excess of 2.0 percent per year. Elasticities appear to be directly related to a region's agricultural infrastructure and its level of agricultural technology as reflected in machinery use (e.g., mechanized plowing, planting, harvesting, and processing), use of chemical inputs (e.g., chemical fertilization and application of pesticides), and use of improved seeds (e.g., hybrid, high-yielding, dwarf, or short stock varieties). Also crucial in regions with higher elasticities were improved managerial practices and availability of inputs. Few if any of the more price responsive regions had sizable subsistence sectors.

Consequently, the highest elasticities—+.1 to +.25—were used in the technologically advanced, heavily commercialized regions using large amounts of high productivity inputs and making heavy capital investments in agricultural infrastructure. Among these regions were most of the developed countries, including both the exporters and the importers. The developed importers (i.e., the EC-9, Other Western Europe, Japan) were found to have higher yield elasticities than the exporters (e.g., the United States, Canada, Oceania) because of tighter constraints on the importers supply of arable or potentially arable land.

The lowest elasticities—+.01 to +.10—were found in the largely subsistence, low technology regions of the developing countries. Elasticities were low in the developing countries well endowed with arable land; elasticities were also low, however, in the subsistence, low technology areas of South Asia faced with severe arable area constraints. In a limited number of land-short, partially developed countries, including the high income East Asian countries, elasticities were found to be appreciably higher than in the rest of the developing countries and, in a few cases, comparable to levels reported in land-extensive developed exporting countries.

CONTRIBUTIONS TO ANALYSIS OF WORLD FOOD PROBLEMS

This chapter summarizes the principal sources—both published and unpublished—that went into development of the GOL model and its use for delineating world food and agriculture in 1985. Background is also presented for the reader interested in technical development of the model. Researchers interested in aspects of the world food economy will also find this a guide to some basic sources.

Organizations

A number of organizations—public and private, domestic and foreign, national and international—are interested in world food problems and agricultural commodity projections. Two with ongoing research and analysis of long-term aspects of food and agriculture are the Economics, Statistics and Cooperatives Service (ESCS) of the U.S. Department of Agriculture (USDA), and the Food and Agriculture Organization of the United Nations (FAO). These two institutions have also been the primary publishers of formal projections studies; these published studies are discussed in the next section.

Over the years, ERS 6/ has conducted agricultural commodity analysis and projections, on both a U.S. and international basis, and has contributed to an expanding literature on aspects of the world food problem.

The Foreign Agricultural Service (FAS) and the Science and Education Administration (SEA), two other USDA agencies, share with ESCS a responsibility for analysis of the world food problem. FAS implements U.S. agricultural policy abroad and collects agricultural data from foreign countries. SEA is concerned with technological aspects of U.S. and world food production. Inevitably, these agencies become involved with the social and economic implications of their work.

FAO is concerned with comprehensive data development, analysis, and policy formulation for world agriculture, and with ongoing appraisal of the world food problem. Much of the best analytical work of FAO, useful to development of the GOL model, is that of the Committee on Commodity Problems, an advisory body composed of national member governments charged with reviewing FAO's commodity analysis.

In addition to the USDA and FAO, numerous organizations share serious concern for world food and agriculture. Other U.S. cabinet departments are heavily involved in aspects of world food and agricultural conditions. Monetary and financial considerations involve the U.S. Department of the Treasury. Trade and commerce involve the U.S. Department of Commerce and the International Trade Commission. Negotiation with foreign governments brings in the U.S. Department of State. The U.S. Agency for International Development provides financial resources and technology assistance to countries with problems of production and marketing of food and agricultural commodities. Its role is policy implementation rather than research and analysis per se. The White House itself calls for policy evaluation from time to time in this general area.

6/ As of January 1, 1978, the Economic Research Service (ERS), Statistical Reporting Service (SRS), and Farmer Cooperative Service (FCS) were merged into the Economics, Statistics, and Cooperatives Service (ESCS). Hence, for the purpose of this report the terms ERS and ESCS are interchangeable.

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Editor's note: The following material on the three U.S. Department of Agriculture submodels is reprinted from: *The Global 2000 Report to the President*, vol. 2, pp. 549–50.

The Three Submodels

The three submodels — arable area, total food (production and consumption), and total fertilizer use — were extremely simple, but they can be described only approximately because the Department was unwilling or unable to provide documentation. The descriptions that follow are based largely on oral responses to questions about the submodels.

The submodels have a few common characteristics. They were all specified seperately for each region in the GOL model for which reliable historical data were available. The submodels were all executed after the GOL model and were dependent on the GOL model in various ways. The function of the submodels and their various assumptions must be described separately.

The arable area submodel supplements the GOL model by providing projections of arable area. The availability of arable land depends on many trends, including urbanization and land reclamation. It is assumed in this submodel that there is a finite amount of land that is potentially arable, and projections are not allowed to exceed this constraint. Up to this constraint, arable area is projected to increase on the basis of time trends and an index of GOL food prices (intended to reflect economic incentives). It is assumed that there will be no large-scale loss or degradation of arable land due to mismanagement or environmental deterioration.

The total food submodel augments the GOL projections (of grains, oilseeds and livestock) to arrive at total food projections. The procedures involved were extremely simple. Growth in total food was in most cases projected as a function of growth in the GOL commodities (grain, oilseeds and livestock) based on historic trends. Their relationship was almost always assumed to be constant over time and linear. Sugars, starches, tropical products and other livestock were taken into account, as appropriate, in the various regions. Fish catches for human consumption were not explicitly taken into account for any region (except Japan), but were included in the analysis of a miscellaneous category. This miscellaneous category was assumed to provide the same percentage of the food supply in the future as in the past. This in turn means that (for all regions except Japan) the fraction of food needs met by fish consumption will be constant, unless substituted by another food in the miscellaneous category (e.g., bananas, goats, camels, etc.). Since food consumption is projected to grow dramatically in all regions, it follows that (in the absence of major shifts to other foods in the miscellaneous category) there will be dramatic growth in the global fish catch. Such growth in fish catch contradicts the Global 2000 Study's fisheries projections.

The fertilizer use submodel supplements the GOL model by providing projections of total fertilizer use. The projections are highly aggregated. The relative amounts of nitrogen, phosphorous and potassium are not given. The aggregate projections are based on regional time-series and cross-sectional relationships involving yields per hectare and growth in crop production. The relationship between fertilizer use and crop production levels is generally assumed to be linear, but the coefficients are adjusted by Departmental analysts (depending on the length of the projection being developed) to reflect assumptions of decreasing return to scale. Decreasing returns to scale are thus specified indirectly (as a function of time) rather than directly (as a function of fertilizer use).

6 The Energy Sector

Introduction

There are two aspects of energy projections: the geological and economic classification of fuel mineral resources, and the economic estimation of supply and demand balances for various energy forms.

The model employed in geological and economic classification of fuel mineral resources is essentially identical to that used for nonfuel minerals, and the interested reader is referred to the discussion of the "McKelvey box" in the next chapter (Nonfuel Mineral Sector).

The Government's model for projecting world energy supply and demand balances is complex. The Department of Energy (DOE) projection model is called the International Energy Evaluation System (IEES). The documentation available to the Global 2000 staff at the time the energy model was being reviewed consisted of two documents: (1) a draft "Methodology"[1] appendix intended for publication in the *Annual Report of the Administrator,* Energy Information Administration (EIA), within DOE, and (2) a document[2] describing part of the demand submodel of IEES. The draft "Methodology" appendix was never published, but was the best source available to the Global 2000 staff. It provides a brief overview of the entire IEES model and is reproduced here. The document describing part of the demand submodel is much more detailed, but not especially helpful in understanding the whole IEES model because it deals with only part of one of the six major submodels. Only the overview description of the demand submodel is repeated here.

The "Methodology" paper that follows will provide the reader with a general sense of the IEES model. Readers interested in further information on the IEES model are referred to a two volume report[3] on the model, which was not available at the time the Global 2000 Study was attempting to review the IEES model.

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1. Mark Rodekohr and Colleen Cornett, "Methodology," an unpublished draft appendix prepared originally for the 1978 *Annual Report of the Administrator,* Energy Information Administration, Department of Energy.
2. Derriel Cato, *An Analysis of OECD Country Energy Demand,* 77-WPIA-19, Washington: Federal Energy Administration, Aug. 1977.
3. Michael L. Shaw and Mary J. Hutzler, *The International Energy Evaluation System,* vols. 1 and 2, HCP/18602-01, Washington: Department of Energy, 1979.

Editor's note: This section is an unpublished draft appendix by Mark Rodekohr and Colleen Cornett. The appendix was drafted originally for publication in the 1978 *Annual Report of the Administrator*, Energy Information Administration, Department of Energy.

Methodology

Introduction

The analysis in this report was supported and validated by a large detailed equilibrium model of the free world energy market referred to herein as the International Energy Evaluation System (IEES).

After first contrasting the approach used here with that of other studies, this appendix reviews the methodology and data utilized in the forecasting approach. IEES is based substantially on the methodology developed for the Project Independence Evaluation System (PIES) and described in detail in the National Energy Outlook for 1976.

A Methodological Approach

Published energy analyses and forecasting are practiced at two levels of detail. In one, "the GDP multiplier approach," total demand for energy is forecasted on the basis of economic growth. Indigenous supplies are considered additively in providing for demand and any excess is considered to be importable from international trade. This approach is the basis of most policy documents and recent projections.*

While this approach is much to be commended for its simplicity and directness, indeed it has been used in IEES for the developing countries, it brushes many of the key issues under the collective rug known as the "estimate of the GDP multiplier," that relates economic to energy growth. Vigorous policies of energy conservation, pricing, and controls result in lower values while expansionist policies and high consumption result in higher values. Countries with low average

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* See for example

1 "World Energy Outlook," OECD, March 1977.

2 CIA International Outlook, April 1977.

3 Energy Global Prospects 1985-2000. Workshop on Alternate Energy Strategies, McGraw Hill Press, 1977.
This is true of some of the WAES national studies; however, the revised overall integration methodology also falls into the second "market method."

GDP multipliers -- Sweden and Germany -- are analyzed as examples for other countries. The fact that the annual variation in the GDP multiplier for any one country often exceeds the variance over all others, remains as a curious if not embarrassing detail of the method.

The second method of energy analysis is more demanding and consequently has little public usage except by companies, organizations, and others for whom the energy trade is a livelihood.

In the second "market method," a detailed model of the energy market is established in which consumption is estimated by econometric analysis of historical and current data, and supplies are evaluated competitively through an existing transportation, processing, and conversion technology. Based upon this analysis, consumption responds to but is not determined solely by economic growth, and supplies need not be additive or even usable in the satisfaction of demand and, thus, determination of import dependence.*

The second method generates a vehicle that is responsive to the conceptual manipulations of the market by policy analysts and yields a detailed understanding of its response.

In particular in determining the demand for petroleum products and, thus, crude oil, it is equally crucial to study the market for non-petroleum products in detail.

The analysis developed in this study adds another element to the technique of the "market method" by explicitly considering the effect of energy prices on consumption. The purpose is to permit the evaluation of the competitive positions of coal, oil, and natural gas in an International market in which the marginal supply of oil, from OPEC, is susceptible to price control. The key issue is to evaluate the market for OPEC oil as a function of price. However, this analysis also provides a means for evaluating national policies since the detailed market model provides an explicit treatment of many of the vehicles of policy implementation -- tariffs, taxes, demand management, regulations, price control, etc., in energy trade, refining, utilities, synthetics, and consumption by sector.

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* See for example

1 The National Energy Outlook, 1976, GPO.

Overview

IEES calculates snapshots of average annual world energy balances and equilibrium prices, for base years in the range 1977-1990. The energy market is considered as the detailed interaction between five major energy consuming areas: the U.S., Japan, Canada, OECD Europe and Australia/New Zealand. OPEC, the remaining non-OPEC LDC's, and the centrally planned economies of Russia, East Europe, and China are considered in less detail. Collectively these are represented in 12 regional descriptions whose emphasis is on the OECD countries because they consume roughly 80 percent of free world oil.

Energy trade is considered as a fully competitive market for indigenous and imported resources of oil, coal, natural gas, and nuclear, hydro and geothermal energy, subject to distortions imposed by various national policies such as regulation, price control and cartelized price fixing.

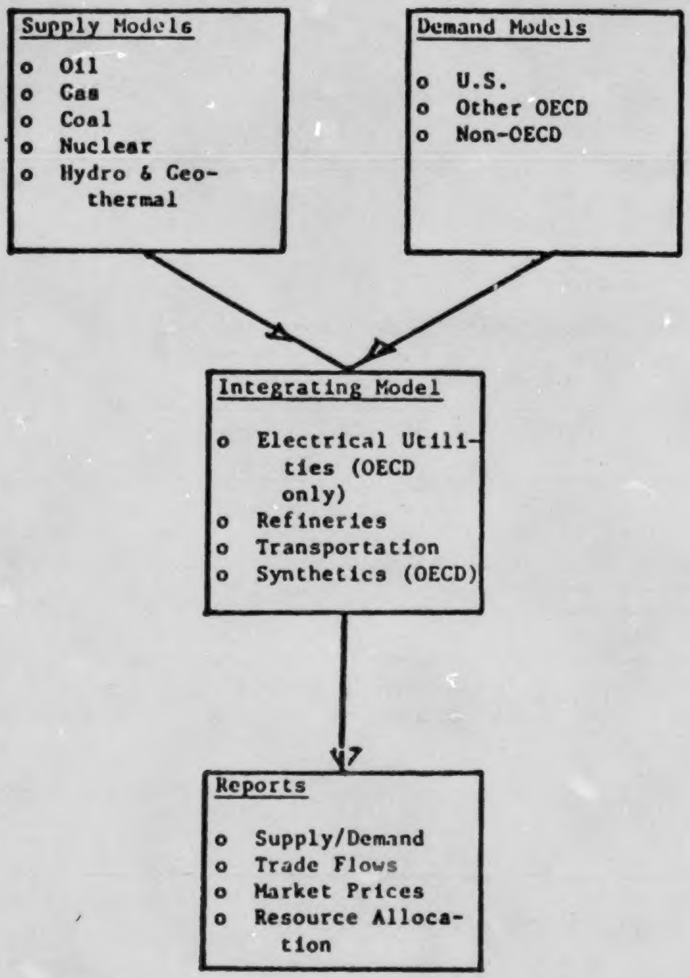
Given an OPEC oil price, specifically for its marker crude, world energy supply, demand, and prices are established by a competitive equilibrium in which consumption and supply are determined by price, consistent with the free world's current and forecasted ability to convert primary energy into final consumption. Figure B-1 shows the general structure of IEES.

The basis of the IEES methodology is the dynamic forecast of annual energy demand from 1975 to 1990 based upon a specific energy price and national income projection. Giving a base price forecast by region for the major fuels (gasoline, distillate, residual fuel, jet fuel, electricity, natural gas and coal), an annual forecast for 49 products by region by sector is developed. By successively perturbing the base prices independently, annual elasticity matrices can be developed for the effect of changes in the base price on the demand forecast. The prices are defined to be the wholesale price on the coast or principal port of loading for the region involved, less taxes or tariffs.

In each region, the supply models consist of representative supply estimates in the form of incremental supplies available as a function of indigenous wholesale price for coals -- steam coal, lignite, metallurgical coal; oils, by source; and gas by source.

In each region, crude specific refinery models transform the oil to products and in OECD regions detailed capacity and fuel specific electrical utility models generate electricity. In non-OECD regions, demand is defined to include utility inputs rather than outputs. In OECD regions, the principal conversions of metallurgical coal to coke, manufactured and blast furnace gas transactions are modeled.

Figure B-1. The IEES System Structure


Supply Models
o Oil
o Gas
o Coal
o Nuclear
o Hydro & Geothermal
Demand Models
o U.S.
o Other OECD
o Non-OECD
Integrating Model
o Electrical Utilities (OECD only)
o Refineries
o Transportation
o Synthetics (OECD)
Reports
o Supply/Demand
o Trade Flows
o Market Prices
o Resource Allocation

Finally, the transportation of raw materials and products via tankers, bulk carriers, rail, and pipelines is modeled to interconnect the regions.

The United States representation in the IEES models is at two levels of detail. For precise representation of the multi-fuel substitution capabilities, the PIES model is coupled directly to the IEES model, and the two are solved simultaneously with consistent scenario specifications. Alternatively, for studies relating principally to oil, it suffices to represent the United States' import demand as a price sensitive oil demand in the IEES model.

Caveats and Assumptions

As discussed in the body of this report, the results of the forecasts must be interpreted with care because they are tied to specific assumptions and do not include future policies or changes introduced by other countries or major structural changes that could be induced by higher oil prices.

A cautionary note is necessary on the subject of links between real economic growth and the growth in demand for energy. Although the demand forecasts are based intimately on economic growth forecasts, there are feedbacks from the energy market to economic forecasts. Thus, a supply shortfall that induced sharply higher energy prices would have an effect on the growth of demand, thus, easing the shortfall. This effect is obviously much more important in nations where imported energy is a larger component of GDP than for the U.S. However, as a secondary effect, U.S. growth is itself determined by trade with the countries that could be most seriously affected.

The analysis makes several fundamental assumptions in addition to scenario specifications.

- International energy trade, supply, and demand is determined by a classical equilibrium constrained by OPEC supplies and prices.
- The model considers only a partial energy sector equilibrium and assumes that the economic effects due to linkage of prices on economic growth and international trade are considered exogenously.
- All institutional aspects affecting consumption are specifically captured by the time series describing consumption and continue at their 1960-1974 trend.

- Natural gas pricing in OECD countries is essentially average pricing whereas marginal pricing holds for all other energy commodities including electricity.
- U.S. product imports are constrained by their 1973-1975 peak levels as a proxy for product import tariffs.
- The U.S. does not export Alaskan oil or natural gas.
- All conservation effects currently observed internationally are directly attributable to price effects.

The model's structure varies by sector. The first three sectors to be discussed, iron and steel, other manufacturing, and residential/commercial, are identical in structure where fuel substitution is emphasized. The methodology used in the determination of these sectoral demands is similar to that used in the PIES demand model. The remaining sectors utilize either a single equation flow-adjustment representation or static formulation depending upon the particular fuel.

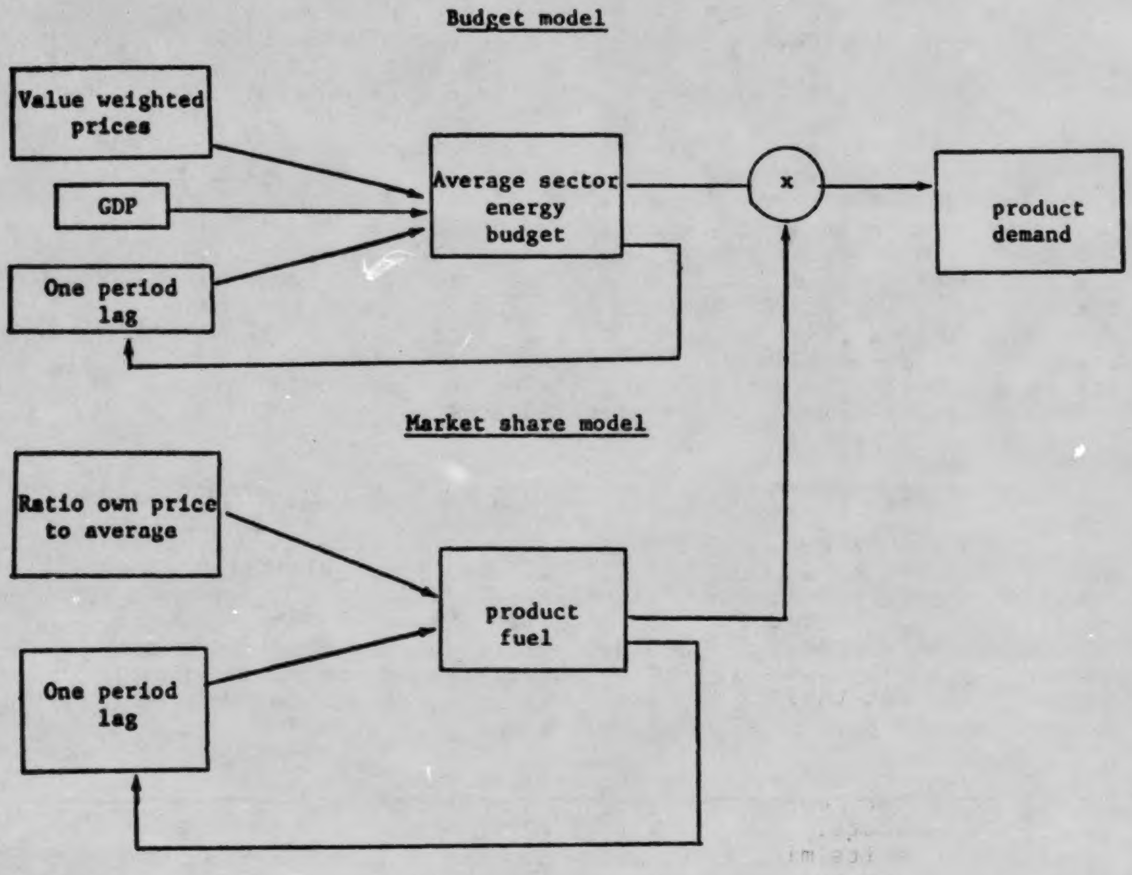
Iron and Steel, Other Manufacturing, Residential and Commercial

The model structure encompassing these sectors is identical and is designed to capture "budget" effects through changes in the level of prices and fuel substitution effects through changes in relative prices. The model can be given the following heuristic interpretation: Consumers of energy first determine a total BTU budget based upon the level of energy prices, incomes, and past behavior and secondly, given the BTU budget, determine fuel choice based upon relative prices and past behavior (capital stocks).

The quantity data is derived from the OECD publication Statistics of Energy, the macroeconomic data comes from the OECD Economic Indicators, and the retail price data comes from selected OECD and non-OECD sources. The period of estimation is from 1961 to 1974. The estimation technique is a generalized least squares method of pooling cross section and time series data.

Figure B-2 illustrates the determination of each sector's product demand. The average (value weighted) sectoral energy budget per capita is econometrically estimated as a function of a value-weighted price index, gross domestic product (GDP) per capita, and a lagged endogenous variable. The value-weighted price index is used to account for differences in end-use efficiencies, GDP is the measure of economic activity, and the lag term is used to approximate overall capital stock changes. The product fuel ratios (ratio of the product to the value-weighted

Figure B-2. General Demand and Model Structure


Budget model
Value weighted prices
GDP
One period lag
Average sector energy budget
x
product demand
Market share model
Ratio own price to average
One period lag
product fuel

energy buget) are estimated as a function of the ratio of product price to the value-weighted average price and a lagged endogenous variable. The sectoral product demand is simply the product of the fuel ratio and sectoral demand.

The only exception to this general structure is in the iron and steel sector where total demand is estimated as function of iron and steel production instead of GDP. The iron and steel model also attempts to capture indirectly the demand for coke-oven-gas and blast furnace gas. Blast furnace gas is captured and either used as a source of industrial heat or used for electrical generation. Since both coke-oven-gas and blast furnace gas are by-products, they are not considered as substitutes for the budget fuels.

Transportation Sector

In the transportation sector, a dynamic flow adjustment model is used for each of the major fuels: gasoline, jet fuel, and diesel fuel while a static single equation approach is used to estimate the remaining minor fuel demands. This method precludes fuel substitution in this sector, a result consistent with most mode choice decisions.

Non-Energy Petroleum Sector

The fuels comprising this sector are napthas, petroleum coke, and the like. Due to data limitations, only total non-energy petroleum was statistically estimated using a log-linear relationship with the various products, shares were assumed to be maintained at their 1974 levels.

Energy Sector

This sector represents final energy consumption by producers of energy products. For example, a coal mine's consumption of electricity in its mining operation appears as final user demand in the energy sector. Since consumption in this sector is strongly related to production, average historical relationships between product consumption and the relevant production variable were assumed to hold for the forecast period. Fourteen separate relationships were estimated. Examples are: electricity consumption by coal mines is related to the production of coal; electricity consumption by electricity generating plants is related to the production of electricity; gas consumption by the gas works is estimated as a function of gas production.

Model Parameter Estimates

As was previously discussed, the model contains estimated equations for 49 energy products in 19 countries. Therefore, the number of estimated equations is well over 100 and too numerous to list in this appendix. However, the major budget equation estimates in Iron and Steel, Other Manufacturing, and Residential/Commercial sectors can be presented. The estimates for the price, income, and the lag term are summarized in Table B-1. For the most part, the estimates all have the correct sign -- a negative sign on the price term and positive signs on the income and lag terms. Furthermore, the value of the lag term lies between zero and one, a necessary condition for stability. The values indicate a generally good fit across all sectors.

Model Performance

The performance of the model can be illustrated grossly by the estimated and actual comparison of final demand by region in Figure B-3.

OECD Demand Model Price and Income Elasticities

In this section, we present a summary of some of the aggregate elasticities. In the actual IEES system, most of the 49 fuels in each of the 4 regions contain both own and cross price elasticities of demand. The full elasticity matrix is too large for presentation in this appendix, so a summary of some aggregate elasticities is presented in Table B-2.

These elasticities represent the change in the final demand of each fuel with respect to a change in the price of all four aggregate fuel types. Therefore, each row of the matrix corresponding to own price elasticities should have a negative sign, while all other rows should be positive, representing interfuel substitution. Except for the (small) negative cross-elasticity between natural gas and other fuels, all of the cross elasticities are positive.

The GDP elasticities for 1985 are summarized in Table B-3. Except for coal (exclusive of utility consumption), all of the elasticities are positive and slightly greater than one in value.

National Resource Estimates

The supply estimates (at current real prices) used in IEES are derived by analysis of various national forecasts of energy

Table B-1. Budget Equation Estimates: Sector Summary

Sector	Joint Coefficients and t-statistics			Regionally Specific R-bar-squared and Durbin-Watson statistics							
	Price	Income*	Lag	Canada	Japan	Austria	Belgium	France	W. Germany	Italy	U. Kingdom
Iron and Steel**	-.15 (12.7)	.45 (18.9)	.60 (37.5)	.95 1.21	.99 1.15	.93 1.53	.98 1.32	.95 1.03	.95 1.45	.93 0.81	.85 1.28
Other Manufacturing**........	-.22 (16.9)	.99 (23.6)	.19 (18.7)	.86 0.66	.99 1.43	.92 1.88	.88 0.35	.96 1.33	.95 0.62	.81 0.85	.87 1.71
Residential/Commercial	-.25 (4.62)	.72 (9.45)	.50 (9.66)	.94 1.08	.96 0.30	.91 0.25	.65 0.34	.98 1.01	.99 1.29	.96 0.41	.38 1.03

*For the Iron and Steel Industry, the level of steel output is used instead of income.

**T-statistics may not be reliable because of technical non-convergence of the estimation program.

Editor's note: The numbers along the axes of these graphs are illegible in the best copy of this paper now available from the Department of Energy.

Figure B-3 Actual and Forecasted Final Demands by Major Region

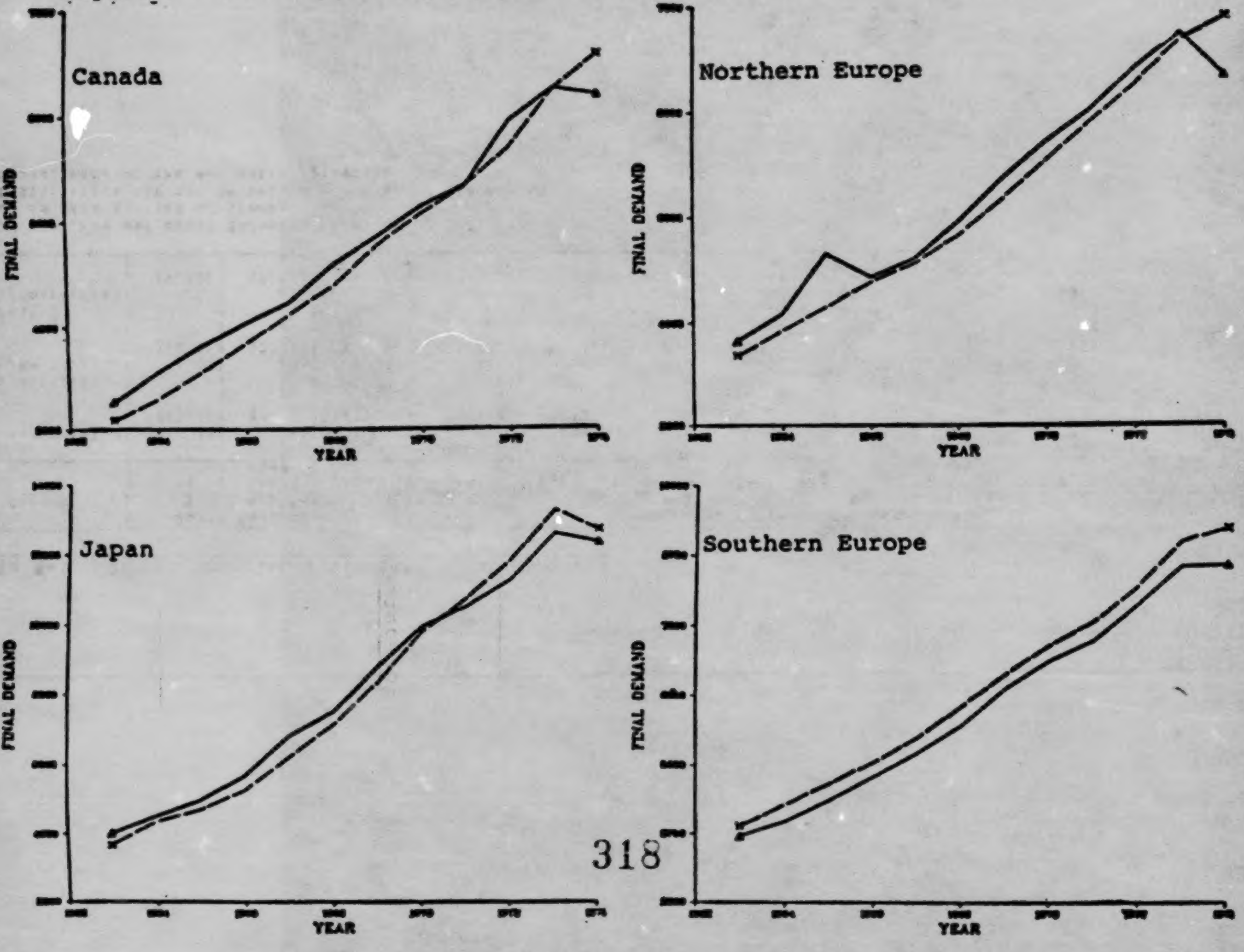


Table B-2. Aggregate Retail Price Elasticities of Demand in Five Major Regions for 1985

	U.S.	CANADA	JAPAN	NORTH EUROPE	SOUTH EUROPE
Solid Fuels:					
Solid Fuels	-.215	-.75	-.94	-1.02	-.94
Natural Gas	.005	.004	-.008	.03	-.008
Electricity	.011	.009	.006	.03	.007
Petroleum	.002	.002	.002	.02	.002
Natural Gas:					
Solid Fuels	.030	.10	.06	.19	.03
Natural Gas	-.426	-.20	-.12	-.17	-.17
Electricity	.052	-.0008	.002	.00	.005
Petroleum	.013	.01	.006	-.0005	.006
Electricity:					
Solid Fuels	.131	.32	.44	.49	.22
Natural Gas	.228	.08	.04	.07	.09
Electricity	-.376	-.42	-.40	-.41	-.38
Petroleum	.077	.07	.08	.04	.06
Petroleum:					
Solid Fuels	.031	.18	.33	.21	.16
Natural Gas	.062	.10	.08	.05	.06
Electricity	.111	.08	.12	.06	.07
Petroleum	-.263	-.48	-.28	-.31	-.30

Table B-3. Aggregate GDP Elasticities in Four Major Regions in 1985

	CANADA	JAPAN	NORTH EUROPE	SOUTH EUROPE
Solid Fuels	-.69	-.46	-.72	-.52
Natural Gas	.86	.92	.75	.78
Electricity	1.28	1.19	1.30	1.22
Petroleum	1.06	1.26	1.43	1.33

supplies provided by the International Energy Agency (IEA), the Organization of Economic Cooperation and Development (OECD) and other sources. No attempt has been utilized to explicitly model the supply potential of other countries, but rather the national estimates are used directly, tempered only where necessary by FEA judgment to reflect the specific scenarios to be evaluated in this report.

Except for Saudi Arabia, Kuwait, Iraq, the United Arab Emirates, Qatar, and Libya, actual production levels by individual countries are assumed to be equal to productive capacity. However, due to excess oil revenues well beyond current economic requirements, the Saudi group of suppliers have been willing to accept production levels significantly below productive capacity. This group of countries acts as the residual supplier of oil to the world and, therefore, has economic control of incremental world oil supplies and ultimately world oil prices. This incremental production is allocated on a productive capacity basis with Saudi Arabia, for example, assuming the largest share. Since the model treats these countries as the residual source of supply, no production limit is imposed. OPEC production sharing percentages are shown in Table B-4.

Table B-4. OPEC Production Sharing Percentages 1980-1990

	1980	1985	1990
Iraq	12.3	13.7	16.9
Kuwait	10.6	10.2	10.1
Libya	8.8	8.5	8.5
Saudi Arabia	56.3	54.6	54.0
United Arab Emirates/Qatar	12.0	13.0	10.5

Electric Utilities

In medium term energy models, utility modeling is the most important conversion process because it defines a significant capability of substitution among coal, oil, natural gas, and nuclear energy to produce electricity. Because these fuels have widely differing availabilities and costs, accurate utility modeling of generation capacity from coal, oil, and gas is essential to capture demand for oil.

Utility generation models are complicated by the fact that the generation cost of electricity is a function of capacity utilization and electrical demand is a function of time of year. Base loaded nuclear generation is relatively cheap at high utilization rates but extremely capital intensive. Peak loaded gas turbine generation is relatively expensive and has low capital requirements. Thus, the nature of the load curve has a primary influence on the choice of generation types./2

Conventional Thermal Generation

This category includes all conventionally-fired boiler-steam-driven power generation. The principal problem is to model fuel requirements, fuel type, capacity and generation costs.

The data sources available dictate a somewhat unique approach. Outside of the U.S., most data are readily available for EEC countries (comprising most of Western Europe) and Canada. At a lower level, OECD data sources provide good background coverage that has yet to be updated.

In general, existing aggregate thermal capacity is allocated by country on the basis of fuel shares at efficiences, utilization rates and reserve margins consistent with the latest data year available, usually 1975. This is because fuel specific capacity data is not generally available. However, data on capacity, generation peak loads and also quantity and quality of fuels burned are available from OECD sources for 1975. Tables B-5 and B-6 show sample fuel shares and specific fuel efficiencies aggregated by region. Table B-7 shows utilization rates by country. The historical nuclear utilization rates are replaced by 0.65 for all countries for projection purposes.

For EEC countries, Canada and Japan, detailed fuel specific capacity data are available, together with recent statistics on generation and quantity and quality of fuels burned. For these countries, a detailed model of fuel specific capacity is utilized that can allocate multi-fuel capacity to any fuel source on the basis of economic choice.

For existing capacity, fuel efficiencies, utilization ratios, and fuel quality are deduced from the most recent statistics of fuels burned. Each unit of capacity is assumed to generate 97 percent base electricity and 3 percent peak electricity. In addition, existing and planned capacity is constrained to be utilized although a lower bound is calculated for all existing capacity based upon a 3 percent per annum retirement schedule. If the unit is uneconomic, it may be partially retired.

Fuel quality varies remarkably by region. Table B-8 shows the derived qualities utilized throughout the utility

Table B-5. Regional Fuel Shares Data (Fraction)

(Actual modeling is by country.)

Region	Coal	Lignite	Residual	Crude	Natural Gas	B.F. Gas	Total
Canada....................	0.527	0.076	0.153		0.244		1.000
N. Europe	0.393	0.131	0.264		0.169	0.042	1.000
S. Europe	0.106	0.090	0.700		0.047	0.057	1.000
Japan	0.042		0.599	0.253	0.055	0.049	1.000
Australia/New Zealand	0.706	0.193	0.056		0.045		1.000

Table B-6. Specific Fuel Efficiency in Power Generation by Region*

(Actual modeling is by country.)

Region	Coal ST per MWH	Lignite ST per MWH	Residual BBL per MWH	Crude BBL per MWH	Natural Gas 000 CU.FT. per MWH	B.F. Gas 000 CU.FT. per MWH
Canada....................	0.479	0.979	2.293		11.700	
N. Europe	0.505	1.509	1.725		8.646	95.882
S. Europe	0.615	1.574	1.778		9.059	98.538
Japan	0.434		1.656	1.656	7.227	89.813
Australia/New Zealand ...	0.400	1.389	1.463		9.593	

* The efficiencies in this table reflect the varying BTU content of the regional fuels consumed.

Table B-7. Historical Utilization Rates by Country

Country*	Nuclear	Thermal	Hydro	Geo-thermal
WG	0.712	0.460	0.323	
AU		0.421	0.310	
AS		0.440	0.400	
BL	0.440	0.482	0.057	
DE		0.341	0.304	
SP	0.799	0.355	0.333	
FI		0.427	0.559	
FR	0.674	0.445	0.394	
GR		0.537	0.333	
IT	0.752	0.460	0.310	1.000
IL		0.499	0.112	
IC		0.058	0.550	**
JP	0.478	0.524	0.409	
LX		0.497	0.008	
NO		0.281	0.488	
NE	0.717	0.435	0.0	
PR		0.251	0.427	
UK	0.664	0.406	0.177	
SW	0.710	0.449	0.534	
SZ	0.685	0.401	0.345	
TU		0.504	0.347	
CA	0.685	0.400	0.642	

*Country definition is as follows: WG-West Germany; AS-Austria; BL-Belgium; DE-Denmark; SP-Spain; FI-Finland; FR-France; GR-Greece; IL-Ireland; IC-Iceland; IT-Italy; LX-Luxembourg; NO-Norway; NE-Netherlands; PR-Portugal; UK-United Kingdom; SW-Sweden; SZ-Switzerland; TU-Turkey; AU-Australia/New Zealand; CA-Canada; JP-Japan.

**Derived from production at 100% utilization.

***Iceland is considered to be energy self sufficient.

Sources: Electrical Energy Statistics 1975, Eurostat
The Electricity Supply Industry in Australia 1974-1975, Electricity Supply Association of Australia
The Electricity Supply Industry - 23rd Survey, OECD
Statistics of Energy 1973/1975, OECD
Electric Power Statistics 1975, Statistics Canada

Table B-3. Weighted Average BTU Content of Fuels to the Utility Sector - 1974/75

Region	Coal	Lignite	Residual	Crude	Nat. Gas	B.F. Gas	Distillate
Canada..................	21.085	12.958	5.623	5.8	1.015	.112	5.825
N. Europe..............	20.129	6.983	5.270	5.8	1.030	.112	5.825
S. Europe..............	17.262	7.590	5.342	5.8	1.031	.114	5.825
Japan..................	17.717	7.199	5.669	5.669	1.078	.110	5.669
Australia/N.Z..........	23.000	7.198	6.287	5.8	1.032	.112	5.825

Units - Coal and lignite: 10^6 BTU/STON; Residual, crude and distillate: 10^6 BTU/BBL;
Nat. gas and B.F. gas: 10^3 BTU/CU.FT.

sector to provide statistical consistency with observed consumption data. All internationally traded fuels are defined by the global values.

Complete data on currently planned capacity are known by unit to 1980 for all OECD countries. All units are constrained to be used. New capacity is modeled at the regional level using PIES data sources for specifications of generic units to be built.

Nuclear, Hydro, and Geothermal Generation

Data on existing units are readily available giving capacity, generation, and utilization and costs. For nuclear generation, the construction of generic U.S. PWR reactors is permitted by region to meet an independent forecast of nuclear generation by country aggregated to the regional level.

Utilization rates of 65 percent are applied to all existing and new reactors uniformly for all regions for 1980, 1985 and 1990 projections. However, for Canada, the electricity generated by nuclear reactors assumes a 75 percent utilization rate following Canadian experiences with the CANDU reactor.

Hydro capacity is allowed to expand similarly to levels defined by the national hydro-forecasts aggregated by region. However, here the historical regional hydro utilization rates are used to contrast the vast difference between some Canadian projects and the much smaller European or Japanese projects. Geothermal generation is modeled only in Italy based upon 1975 data.

Pricing of Electricity

Since existing generation costs are not available for most countries, the pricing of electricity in IEES is based on the marginal cost of generating electricity. In general, the demand for electricity is greater than existing facilities (both thermal and non-thermal) and planned thermal constructions can supply. For that reason, it is only necessary to supply accurate costs for additional construction of all power generation plant types. The costs included are:

- Amortized construction costs.
- Operation and maintenance costs.
- Marginal fuel costs.

These data compare favorably with available data on national industrial rates for electricity in most countries before taxes.

Synthetic Conversion Process

The synthetic conversion processes modeled by region are the various transactions necessary in the production of metallurgical coke, manufactured gas, producer gas, and briquettes defined in the OECD data sources. They are primarily a means of tracking metallurgical coal demand and industrial gases used for utility generation and are based directly upon the OECD annual statistics.

Refining

The IEES refining submodel is very similar to the PIES refining submodel and provides an integrated analysis of the many crude sources and markets in which the refineries compete. The current representation incorporates 43 crudes, 8 refining regions, 6 final product types, and 10 markets.

The model characterizes the conversion of various types of crude oils into broad categories of refined petroleum products demanded in the integrating model on a price sensitive basis. It provides the flexibility to produce a variable mix of petroleum products for the future product demand patterns while permitting the evaluation of the products and the crude oils in line with historically observed price differentials.

Base Yields

Refinery operations are modeled in a flexible manner. Base operating modes are provided for each crude in each refining region assuming the 1974 operating conditions. The crude specific refining yields are obtained by relating the crude slates and the products yielded by these crude slates in the actual 1974 operations by means of crude oil property attributes contained in the Refinery and Petrochemical Modeling System (RPMS)/3 data base. One or more attributes are selected to predict the yield of a petroleum product. The average actual product yields of the crude slate are assumed to be a function of the average actual attributes. Consequently, the ratio of a specific crude's attribute to the average attribute for a given product is used to predict the yield for the product from the same crude.

Each distillation activity provides the finished product yields and consumes a specific crude. The distillation operation additionally consumes crude unit, cat cracker and reformer capacities. The capacity consumption data are crude specific for the cat cracker and the reformer.n These coefficients are derived in a manner similar to the product yields, i.e., on the basis of crude attributes. A cash operating cost is also associated with each distillation operation.

The operating costs are derived from published data/4 and include a desulfurization charge above the 1974 desulfurization levels.

Shifts From Base Yields

The base yields for individual crudes are augmented by shift activities to provide the flexibility needed to satisfy the changes in the product demand patterns in the marketplace within the technical capability of the refineries. As was outlined in the introduction, the cost of producing each product in the refining sector determines the product values obtained in the IEES model solutions. The product price differentials observed in the international markets are taken as a proxy for the production cost differentials among the various products. An anlysis of the price differentials in the Rotterdam market provided the product cost differential estimates used in the representation of the yield shift activities.

The shift activities allow downgrading or upgrading of the finished products into each other on the basis of product price differentials. These are derived from representative Rotterdam market transactions (expressed as differentials from the value of residual fuel oil). The shift costs and the product volume debits or credits are represented in the model on a BTU equivalence basis and preserve the volumetric material balances.

Refining capacities are modeled for the crude distillation, cat cracking and reforming units. Base refining capacities are those in existence on January 1, 1977. Refinery capacity construction activities are provided both for new grass roots refineries and for debottlenecking the existing facilities. Grass roots refineries are built with a crude distillation/reforming profile. Cat cracking and incremental reforming may be added to the grass roots or existing refineries. The new capacity cost data for the grass roots refining capacity is derived from references in the Oil and Gas Journal/5 while the construction costs for new cat cracking and reforming are derived from the RPMS data base.

Transportation

The transportation submodel of IEES simulates the inter-regional movements of energy resources among. A total of 11 material-transport mode combinations are represented: coal-rail, bulk carrier; natural gas-LNG carrier, pipeline; crude oil-small, medium, and large tanker, VLCC, pipeline; oil products-product tanker, pipeline.

Although intra-regional transportation is not modeled explicitly, estimates of the costs of intra-regional distribution are included as a part of the production and refining costs of the energy resources.

The important physical or technological limitations which affect the distribution of energy are described within these transportation models. The capacities of the energy transportation systems are represented as limits on the total shipments between regions.

The 11 material transport modes involve multiple classes of shipping by size category and cargo handled. Four size categories of oil tankers are specified in order to reflect the differing economics of the various size tankers and to depict the physical restrictions of canal passage and port access. Small tankers are defined to be those that are capable of transit through both the Panama and Suez Canals. Medium tankers are specified to be those too large for Panama Canal passage but which are small enough for the Suez Canal and most ports throughout the world. Large tankers are those whose draft requirements prohibit their direct access to most U.S. and Canadian ports but which normally do have access to other areas of the world. The fourth class, VLCC, includes all tankers which require the availability of superports to offload their cargo and which are too large to transit either canal. It is assumed that large size tankers can transit the Suez Canal whenever sailing in ballast. This routing significantly shortens the travel times of these tankers when returning to the Persian Gulf from their destinations in Europe and the Western Hemisphere.

Transportation costs associated with tanker movements are calculated on the basis of an average of current short- and long-term charter and called "Average Freight Rate Assessment" or AFRA rates. The rates are determined for each size category of tanker and are compiled monthly by the Association of Ship Brokers and Agents. The rates are expressed as a percentage of a set of reference freight rates called "worldscale," which are compiled by the same association and published periodically. Thus, an AFRA rate of 75 for a given size tanker is interpreted to mean that the average freight rate being charged is 75 percent of the reference rates over all trade routes for that size tanker.

Worldscale rates are specified for each major trade route in the world and, in general, vary slightly depending upon the ports utilized. However, since this analysis is concerned with the average rates experienced between major regions of the world, it is sufficient to express the 1975 worldscale rates in terms of a linear regression equation as follows:

$$\text{Worldscale Rate} = 1.26\ (\text{Distance}) + .88$$

where distance is expressed in thousands of nautical miles and the rate is given in dollars per long ton. The regression was derived using a representative set of 1975 worldscale rates with an R-squared goodness-of-fit statistic of 0.9925.

A basic assumption in the model is that the current relatively depressed tanker rates will continue into the foreseeable future. This is obviously a somewhat optimistic estimate of transportation costs. These costs could be higher by sometime in the 1980's if the demand for tankers is substantially increased. However, this bias toward lower rates is not very extreme, as will be explained below, and is done primarily in order to be conservative with respect to the impact of transportation costs on any increases in the price of energy.

Short term shortages in available tankers have historically caused wide variations in the spot and AFRA rates. However, these fluctuations will be greatly diminished for at least the next five years due to the current excess of shipping capacities that has resulted from the decrease in the growth of demand and the excessive building programs for super tankers that have taken place in recent years. It is assumed in IEES that the building of tanker capacity beyond 1980 will keep pace with the rising demand for oil, and thus, the AFRA rates will continue to compare with the long term charter rates and not be biased significantly higher due to a shortage./6

The shipping rates imposed in IEES are adjusted dynamically as a function of the price of bunker fuel. As the price of bunker fuel changes, the transportation costs on each route are adjusted, based upon the usage of bunker fuel on the route for each type of ship. This is accomplished by subtracting the contribution of bunker fuel to transportation costs using current fuel prices and then letting the model determine the level of bunker fuel to be used based upon the actual usage of ships. The model consumes the appropriate quantities of bunker fuel at the prevailing price in each region.

The transportation costs associated with international shipments of coal and liquefied natural gas (LNG) were also established via regression analysis using Bureau of Mines data in the case of coal and FEA estimates in the case of LNG. The freight rates applied in the model are given by the following equations:

$$\text{Coal Rate} = 1.86\ (\text{Distance}) + 4.96$$

$$\text{LNG Rate} = 0.177\ (\text{Distance}) + 0.189$$

where the coal rate is expressed in dollars per long ton and the LNG rate is expressed in dollars per thousand cubic feet of natural gas. The rates assumed for pipelines in IEES are the same as those assumed for the United States.

Data Sources

A great variety of data sources were researched in developing the data base for the IEES model. The most useful and productive sources are listed here.

EEC Countries

1. Eurostate, Electrical Energy Statistics, November 1975.

OECD Countries

2. Electric Supply Industry, 23rd Enquiry, OECD, 1972.
3. 27th Survey of Electric Power Statistics, OECD, 1974.
4. World Energy Outlook, OECD, 1977.
5. Statistics of Energy, 1960-1974, Paris 1975.

Canada

6. Electric Power Statistics, Vol. III, 1975, Statistics, Canada.

Japan

7. Survey of Japanese Market of Electric Energy Systems; prepared for U.S. Department of Commerce by Peat, Marwick, Mitchell.
8. 48th Semi-annual Electric Power Survey, Japan Electric Power Survey Committee, April 1976.

Australia/New Zealand

9. The Electric Supply Industry in Australia, 1974-75, Electric Supply Association of Australia, April 1976.
10. Market Research Study for Australia in the Field of Electric Energy Systems, Price Waterhouse Associates, July, 1975.
11. Reports of the New Zealand Electricity Department, 1976.

FOOTNOTES

1/ Full details can be found in Derriel Cato's paper, "An Analysis of OECD Country Energy Demand," March 1977, Discussion Paper No. 1-02-77.

2/ Full details can be found in Appendix L of the National Energy Outlook for 1977.

3/ RPMS is a commercial data base and matrix generator package available from Bonner and Moore Associates, Inc., Houston, Texas, for modeling refinery and petrochemical operations.

4/ The regional operating costs are derived from a Pace study, "Determination of Refined Petroleum Product Import Fees," July 1976, by the Pace Company, Houston, Texas and consist of salaries and wages, utilities, maintenance, supplies, and catalyst/chemical usage, and taxes/insurance in 1975 dollars.

5/ Oil and Gas Journal, July 15, 1974, p. 87 and July 22, 1974, p. 60. The estimates for the U.S. Gulf Coast have been extended to IEES regions using the location cost factors in the latter article.

6/ See "The World Petroleum Market," Chapter IV, M.A. Adelman, 1974.

Editor's note: The following material is taken from Derriel Cato, *An Analysis of OECD Country Energy Demand,* 77-WPIA-19, Washington: Federal Energy Administration, Aug. 1977, pp. 1–12.

I. OVERVIEW OF THE OECD ENERGY DEMAND MODEL

Introduction

The purpose of this study is to describe the current version of the non-U.S., OECD Energy Demand Model. The description, first, concerns energy variable definitions as used within the modeling structure. Chapter II presents vigorous definitions and displays of the energy balance accounts, as well as a growth rate analysis performed on the historical data. The main concern of the historical analysis is to discern sector and product consumption patterns of the various countries over the period of observation. Following the analysis of energy consumption patterns, growth rates of energy prices and macro-variables are displayed. These data are presented as an appendix to Chapter II.

The subsequent major efforts are placed on the model structure assumed, econometric techniques employed, and the resulting statistical estimates. In order to ascertain the reliability of the model, a historical analysis of the model is made and resulting statistical measures are presented. Finally, the model is simulated from 1975 to 1990 under a reference scenario of prices and macro-variables.

Care must be taken in interpreting the results of this exercise. First, price and other parameter estimates were obtained over a period of declining real energy prices and during a period of rapid economic development of most of the countries included in the sample. Secondly, the simulations represent unconstrained demand forecasts, which necessitates a regime of perfectly elastic supply conditions to be correct. This presumption can hardly approximate a realistic view of the future energy resource market. Therefore, these results are used by the IEES model to produce market clearing prices and quantitites. The forecasts are for final demand products only, sometimes referred to as secondary or converted energy products. Thus, the conversion process to primary energy is not modeled directly. The conversion process includes, among other processes, the electricity generation sector, manufactured gas conversions, and refinery operations. It is also important to note that the historical analysis indicates a large variability in the statistical sample for price, macro, and energy variables. This variability, especially in the price term, provides a sound basis for forecasting future demands with rather large price increases. (Sample variability, of course, is the mainstay of econometric analysis.) The econometric exercise concentrates on substitution and output effects by sector and sector product.

The remainder of this chapter presents outlines of country and product detail, and of the major product model structure. Finally, due to its widespread use by international and other energy bodies, a review of the "energy/GDP multiplier" concept is made and appropriate criticisms are presented.

Country and Product Information

The OECD energy demand model solves energy demands by sector and product for each of 19 countries. (Luxembourg is included with Belgium.)

The model is rich in detail with a total of 6 sectors and 50 products for each of the 19 countries.

The demands in much of the analyses are aggregated into four regions: Canada, Japan, North Europe, and South Europe; however, any other aggregation scheme could be used. The individual countries are summarized in Table 1.1.

Table 1.1: OECD Demand Model Region Definitions

Canada	Japan	North Europe	South Europe
		Austria	Greece
		Belgium	Italy
		Luxembourg	Portugal
		Denmark	Spain
		Finland	Turkey
		France	
		West Germany	
		Ireland	
		Netherlands	
		Norway	
		Sweden	
		Switzerland	
		United Kingdom	

For most of these countries, the demands for a total of 50 products are econometrically estimated. Both the sectors and product detail are summarized in Table 1.2.

Table 1.2: Energy Demand Model Sectoral and Product Detail

Final User Sector	Model	Products
Transportation	Minor	Coal Liquefied Gases Kerosene Distillate Electricity Natural Gas Aviation Gasoline Bunker Fuel
	Major	Gasoline Diesel Oil Jet Fuel
Iron and Steel	Coking	Coke Coke-Oven-Gas Blast Furnace Gas
	Budget	Coal Natural Gas Residual Oil Electricity
Other Manufacturing	Minor	Coke Blast Furnace Gas Briquettes Lignite
	Budget	Natural Gas Liquefied Gases Kerosene Residual Oil Electricity
Residential/Commercial	Minor	Coke Briquettes Lignite
	Budget	Coal Natural Gas Distillate (and Kerosene) Liquefied Gases Electricity

Table 1.2: Energy Demand Model Sectoral and Product Detail (Cont'd)

Final User Sector	Model	Product
Non-Energy Petroleum	Minor	Naptha
		Petroleum Coke
		Lubes
		Waxes
		Asphalt
		White Spirits
		Other
Energy Sector	Minor	Coal
		Lignite
		Coke
		Blast Furnace Gas
		Refinery Fuel
		Natural Gas
		Electricity
		Still Gas

Summary Model Description

The model's structure varies by sector. The first three sectors to be discussed, iron and steel, other manufacturing, and residential/commercial, are identical in structure where interfuel substitution is emphasized. The remaining sectors utilized either a flow-adjustment equation representation or static formulation depending upon the particular fuel.

FUEL BUDGET/SUBSTITUTION MODEL: IRON AND STEEL, OTHER MANUFACTURING, RESIDENTIAL AND COMMERCIAL

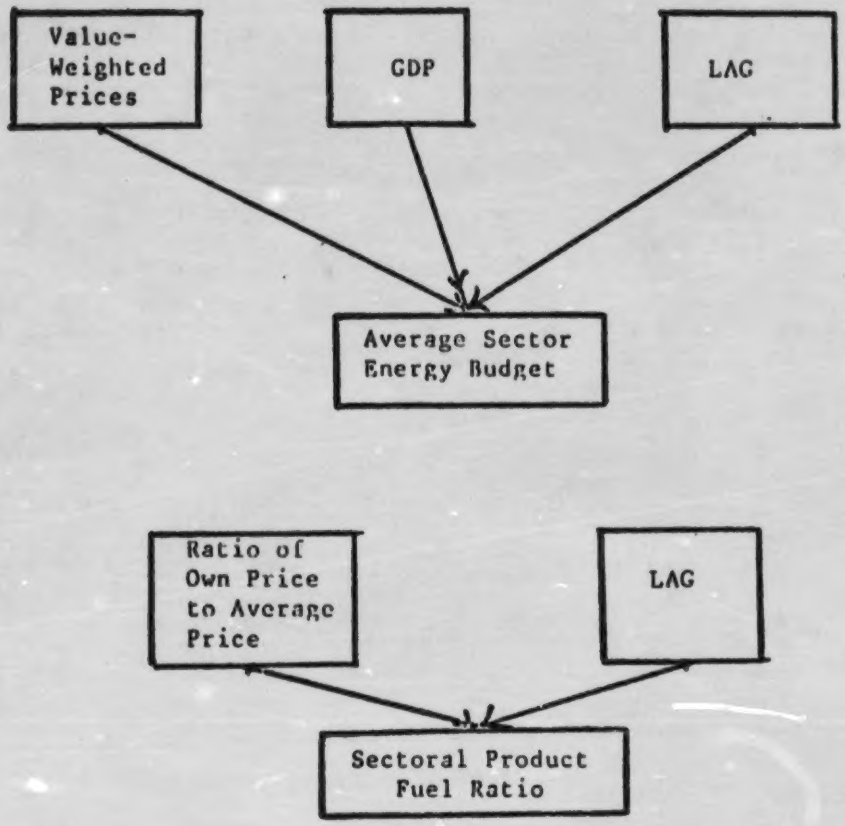
The model structure encompassing these sectors is idential and is designed to capture "budget" effects through changes in the level of prices and fuel substitution effects through changes in relative prices. The model can be given the following heuristic interpretation:

> Consumers of energy first determine a total BTU budget based upon the level of energy prices, incomes, and past behavior, and, secondly, given the BTU budget, determine fuel choice based upon relative prices and past behavior (capital stocks).

Figure 1.1 illustrates the determination of each sectors product demand. The average (value weighted) sectoral energy budget per capita is econometrically estimated as a function of the value weighted prices, gross domestic product (GDP) per capita and a lagged endogenous variable. The value weighted price is used to account for differences in end use efficiencies, GDP is the measure of economic activity, and the lag term is used to approximate overall capital stock changes. The product fuel ratios (ratio of product to the value weighted energy budget) are estimated as a function of the ratio of product price to the value weighted average price and a lagged endogenous variable. The sectoral product demand is simply the product of the fuel share and the total sectoral demand.

The only exception to this general structure is in the iron and steel sector where the total demand is estimated as a function of iron and steel production instead of GDP. However, iron and steel production is, in turn, expressed as a function of GDP. The iron and steel model also attempts to capture indirectly the demand for coke-oven-gas and blast furnace gas. Since both coke-oven-gas and blast furnace gas are by-products, they are not considered as substitutes for the budget fuels.

Figure 1.1: Major Model Description


Value-Weighted Prices
GDP
LAG
Average Sector Energy Budget
Ratio of Own Price to Average Price
LAG
Sectoral Product Fuel Ratio

$$\begin{bmatrix}\text{Sectoral Product}\\ \text{Demand}\end{bmatrix} = \begin{bmatrix}\text{Average}\\ \text{Budget}\end{bmatrix} \bullet \begin{bmatrix}\text{Product}\\ \text{Fuel}\\ \text{Ratio}\end{bmatrix}$$

Transportation Sector

In the transportation sector, a dynamic flow adjustment model is used for each of the major fuels, gasoline, jet fuel, and diesel fuel while a static single equation approach is used to estimate the remaining minor fuel demands. This method precludes fuel substitution in this sector, a result consistent with most mode choice decisions.

Non-Energy Petroleum Sector

The fuels comprising this sector are napthas, petroleum coke, and the like. Due to data limitations, only total non-energy petroleum was statistically estimated using a log-linear relationship with GDP and the price of residual fuel oil. The various product shares were assumed to be maintained at their 1974 levels.

Energy - GDP Ratio

Many forecasts of future energy demand are based upon the notion of a stable energy growth to growth in real gross domestic product (GDP), referred to herein as the "GDP Ratio."

The methodology employed is to compute the ratios over some historical episode and, given projected future GDP growth rates, to multiply the GDP projections times the GDP-Ratio to obtain projected energy demand. Usually judgment is used to modify the historical ratio to allow for sundry effects -- expected future price effects, conservation effects, energy-GDP feedback effects. And usually some "norm" ratio is used to represent a particular country depending upon its stage of development. While forecasts cannot be criticized, methodologies can. Table 1.3 contains historical GDP Ratios for total primary energy and total final demand of various OECD countries; and, as the table indicates, these vary considerably across countries.

Assume for the moment that energy demand (E) depends on log-linearly entirely upon real energy price (P) and real GDP, and no feedbacks, then equation (1.1) depicts energy demand.

$$(1.1) \quad \ln E = a + b \ln P + c \ln GDP$$

Taking derivations of (1.1) with respect to time yields (1.2)

$$(1.2) \quad \frac{d \ln E}{dt} = b \frac{d \ln P}{dt} + c \frac{d \ln GDP}{dt}$$

These relationships can be grouped realistically as in Figure 1.2. The energy growth is larger than GDP growth since declining energy prices influence energy growth in a positive way (b>0).

An examination of Figure 1.2 reveals the limitations of the Energy-GDP ratio. Over the historical period, the growth of real GDP is secularly positive whereas the growth of real energy price is negative. The Energy GDP ratio is:

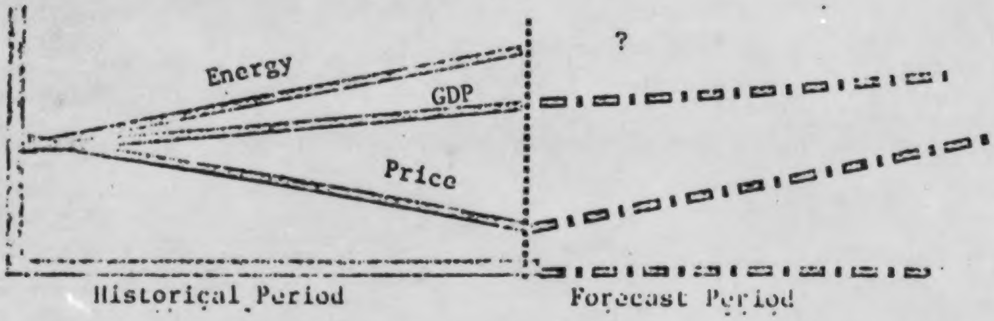
$$\frac{d \ln E}{dt} \Big/ \frac{d \ln GDP}{dt}$$

However, given the forecasted increasing real energy price and constant GDP growth, the ratio analysis would lend one to

Table 1.3: Historical Ratio Energy Growth to Real GDP Growth

	1960-1973		
	Total Consumption	Total Final Demand	Growth Rate Real GDP
Canada	1.31	1.19	5.65
Japan	1.11	1.19	10.18
Austria	1.17	1.14	5.24
BelLux	.95	.96	5.07
Denmark	1.19	1.14	4.62
Finland	1.77	1.96	5.34
France	1.14	1.05	5.59
W. Germany	.95	.93	4.74
Greece	1.35	1.18	8.27
Ireland	1.54	1.47	4.40
Italy	1.84	1.79	4.64
Netherlands	1.57	1.52	5.69
Norway	1.40	1.31	4.44
Portugual	1.22	1.13	7.07
Spain	1.39	1.43	6.67
Sweden	1.57	1.39	3.75
Switzerland	1.56	1.59	3.62
Turkey	1.44	1.39	6.71
United Kingdom	.73	0.51	3.00
United States	1.16	0.92	4.30

Figure 1.2: Secular Growth: Energy, Price, and GDP


?
Energy
GDP
Price
Historical Period
Forecast Period

project constant growth in energy, but price effects would reduce energy growth unless (b=0). Finally, this analysis includes none of the stock dynamics which are so critical to energy analysis.

7 The Nonfuel Minerals Sector

Introduction

The development of nonfuel minerals projections involves two aspects analogous to those used for fuel mineral projections: the geological and economic classification of nonfuel mineral resources, and the economic estimation of supply and demand balances for various nonfuel minerals.

The model or methodology used by the U.S. Government for the geological and economic classification of nonfuel mineral resources is the so-called "McKelvey box." This philosophical scheme for resource classification is described in the first chapter of *Mineral Facts and Problems,* the primary nonfuel minerals report published by the Department of the Interior (DOI). This introductory chapter is reproduced here in its entirety.[1]

The economic estimation of nonfuel minerals supply and demand is also taken up in *Mineral Facts and Problems.* The DOI methodology for estimating future nonfuel minerals supply and demand balances is described in the introductory chapter of *Mineral Facts and Problems.*

The nonfuel minerals projections provided in *Mineral Facts and Problems* and other DOI reports could not meet the Global 2000 Study's needs for regional disaggregation. To obtain more disaggregated projections, the Study followed the recommendation of the Department of the Interior and used projections developed by Professor Wilfred Malenbaum of the University of Pennsylvania. Professor Malenbaum's methodology, known as the Intensity of Use (IOU) methodology, is described in two studies he has conducted for the U.S. government.

The first of Professor Malenbaum's two studies[2] was done in 1972 for the National Commission on Materials Policy. This study contains a relatively brief description of the IOU methodology in a section entitled, "Research Scheme." This one section of Professor Malenbaum's 1972 study is reprinted here.

The second Malenbaum study[3] describing the IOU methodology was done in 1977 for the National Science Foundation. The discussion of the IOU methodology is more extensive in this study. Part II (The Research Scheme), Part III (World Economic Growth: The Prospect for 1985 and 2000), and the inventory pages of Part IV (Intensity-of-Use) are reprinted here.

References

1. "Introduction," in Department of the Interior, Bureau of Mines, *Mineral Facts and Problems,* Washington: Government Printing Office, 1975, pp. 1–34.
2. "Research Scheme," in Wilfred Malenbaum, Carol Cichowski, Fathollah Mirzabagheri, and James Riordan, "United States Minerals Requirements in the Year 2000: Production Implications of Foreign Minerals Requirements in 2000," pp. 1–3, an annex to *Materials Requirements in the Year 2000,* Washington: National Commission on Materials Policy, Nov. 30, 1972.
3. Wilfred Malenbaum et al., "World Demand for Raw Materials in 1985 and 2000," an unpublished report prepared for the National Science Foundation under grant no. 75-23687, Oct. 1977, pp. 18–51.

Editor's note: This section is taken from Department of the Interior, Bureau of Mines, *Mineral Facts and Problems,* Washington: Government Printing Office, 1975, pp. 1-34.

INTRODUCTION

THE IMPORTANCE OF MINERALS IN THE U.S. ECONOMY—1776–1976

The contribution of minerals to the growth and development of the United States is best demonstrated by the uses which have evolved during the past two centuries.

During pre-Revolutionary days the colonies were essentially agricultural in character, producing cotton, tobacco, rice, indigo, grains and flour, fish, livestock, dairy products, and timber. Shipbuilding was the major manufacturing industry. In 1763, the total value of exports for Virginia, Maryland, New York, Pennsylvania, and Massachusetts was £2,722,000, of which £55,000, or 2 percent, was for "copper ore, and iron in pigs" (*3*)[1] and £49,000 was for 21,000 barrels or hogsheads of "pot-ash." The value of 75 ships built for sale in 1763 by the colonies was £61,500.

At the time of the Revolutionary war, mineral materials used per capita are estimated to have been about 1,200 pounds, consisting chiefly of sand and gravel, 1,000 pounds; brick and lime, about 112 pounds; coal, 40 pounds; iron, 20 pounds; and the balance for copper, glass, lead, potash, salt, nitrates, sulfur, and zinc (*14*).

During the 1776–1976 period, the population of the United States has increased from about 2.5 million people to more than 215 million.

Currently, the annual output of the U.S. mining, mineral processing and refining, mineral reclamation, and energy industries is worth more than $270 billion. More than 4 billion tons of new mineral supplies are needed every year in the U.S. economy. From a meager per capita consumption of minerals of about 1/2 ton in 1776, the annual per capita consumption has increased nearly forty-fold, to about 20 tons per person today.

During the first 100 years, science, invention, and discovery evolved slowly; and so did manufacturing and the production of minerals required to support manufacturing. However, the discoveries, inventions, and other developments in the United States and abroad during this embryonic period constituted a springboard for the greatest explosion in inventions, discoveries, innovation, and economic progress the world has ever witnessed, not only in the United States, but in the industrial nations of the world as well. Paralleling this exponential economic growth, is the expanding production of minerals and energy materials, which are critically essential to the growth of industrial nations, and vital to ward off the periodic attempts of world political forces to wipe out the system that made all this progress in humanity possible.

The accompanying chronology of inventions and discoveries in the United States and abroad is highly selective, compiled to identify some of the important events that mark the progress of the United States and the world, and the parallel contribution of the minerals industry to that progress. Figures 1 to 10 show the historical production pattern for gold, silver, pig iron, coal, copper, aluminum, lead, zinc, natural gas, and petroleum. The charts and tables in the chapters of the volume present production and consumption data for more than 100 mineral commodities for the United States and the rest of the world.

Many of the inventions and discoveries cited in the chronological table resulted in the development of large industries, which in turn made heavy demands on the mineral productive capacity of the United States. The automotive industry is a dramatic example.

During the late 1800's numerous inventions of internal combustion engines were made, and between 1880 and 1900 numerous custom-made models were built in the United States and abroad. By 1903, when first reliable motor-car statistics were available, production was reported as follows:

France	30,204
United States	11,235
Great Britain	9,437
Germany	6,904
Belgium	2,839
Italy	1,308
Total	61,927

In 1904, Olds of Detroit manufactured the first mass-produced (more than 10 per week) motor car. In 1908 Henry Ford introduced the Model T and also assembly-line production, which gave great impetus to the motor vehicle manufacturing industry.

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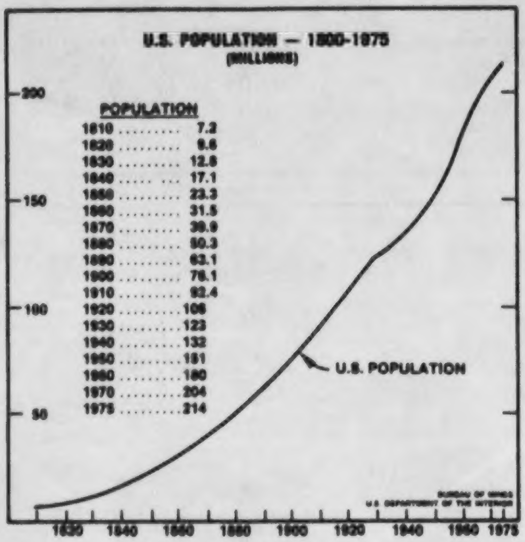
[1] Italicized numbers in parentheses refer to items in the list of references at the end of this chapter.



POPULATION

1810	7.2
1820	9.6
1830	12.8
1840	17.1
1850	23.3
1860	31.5
1870	39.8
1880	50.3
1890	63.1
1900	76.1
1910	92.4
1920	106
1930	123
1940	132
1950	151
1960	180
1970	204
1975	214

Figure 1.—Population of the United States in million of persons, 1800–1975 (6,7).

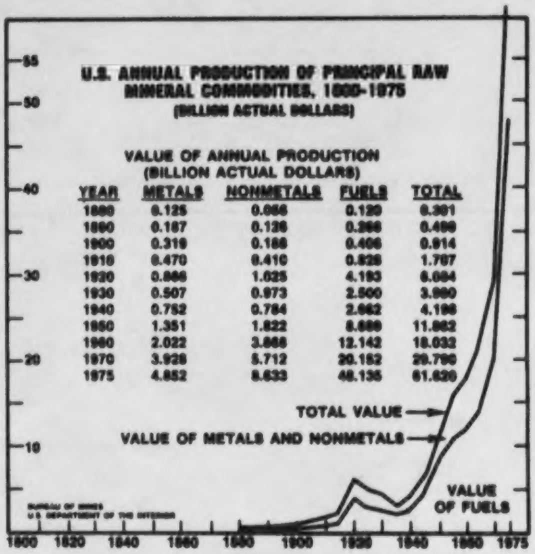
In 1975, motor vehicle production of passenger cars, trucks, and buses totaled 8,981,580 units. Total for the world was 33,193,154 (2). The manufacture of these vehicles in the United States required the following amounts of metals:

	Thousand short tons	Percent of total U.S. consumption
All forms of steel	18,926	17
Aluminum	802	13
Copper and copper alloys	255	8
Lead (includes tetraethyl)	1,000	63
Malleable iron	417	46
Zinc	431	33

Quantities of minerals and fuels required by numerous other industries are given in the supply-demand tables and charts of each commodity chapter, where the amounts required for various end uses such as transportation and machine manufacturing are identified by Standard Industrial Classification (SIC) numbers of two, three, and four digits.

The role of minerals in the U.S. economy at present is depicted in figures 11 to 19, which include per capita consumption of minerals and fuels; production of steel, aluminum, and petroleum; exports and imports; scrap reclaimed; production of plastics which are dependent upon mineral and petrochemical raw materials; and transportation requirements of the minerals industry. See pages 8 to 14, inclusive.

The "Time Capsule" which follows is printed beneath graphs which show the interdependence that exists between invention and industrial development and the production of minerals.



VALUE OF ANNUAL PRODUCTION
(BILLION ACTUAL DOLLARS)

YEAR	METALS	NONMETALS	FUELS	TOTAL
1880	0.125	0.056	0.120	0.301
1890	0.187	0.126	0.186	0.499
1900	0.319	0.188	0.406	0.914
1910	0.470	0.410	0.828	1.707
1920	0.866	1.025	4.193	6.084
1930	0.507	0.973	2.500	3.980
1940	0.752	0.784	2.662	4.198
1950	1.351	1.822	8.689	11.862
1960	2.022	3.868	12.142	18.032
1970	3.928	5.712	20.152	29.792
1975	4.852	8.633	48.135	61.620

Figure 2.—U.S. annual production of principal raw mineral commodities in billion actual dollars, 1800–1975 (*6,13*).

TIME CAPSULE, 1776–1976

Discoveries, inventions, and developments that had an impact of the economic and industrial growth of the United States and other industrial nations of the world are listed in a highly selective and telegraphic style. No attempt has been made to catalog the vast number of discoveries, inventions, and developments that occurred in the 1960's and 1970's.

Pre-Revolutionary Period

1621. The coal-fired blast furnace was used for iron smelting in Great Britain.

1624. First wooden submarine was built by the Dutch and operated successfully on the floor of the Thames River.

1627. Earliest record of oil in the United States near what is now Cuba, N.Y.

1629. The steam jet turbine was described.

1634–74. Coal was noted in northern Illinois.

1648. A gas-turbine device consisting of a rotor driven by hot rising gases in a cylinder was demonstrated in Great Britain.

1661–81. First use of black powder and hand drilling in a public-works tunnel in France.

1684. First agricultural application of steam power in Great Britain.

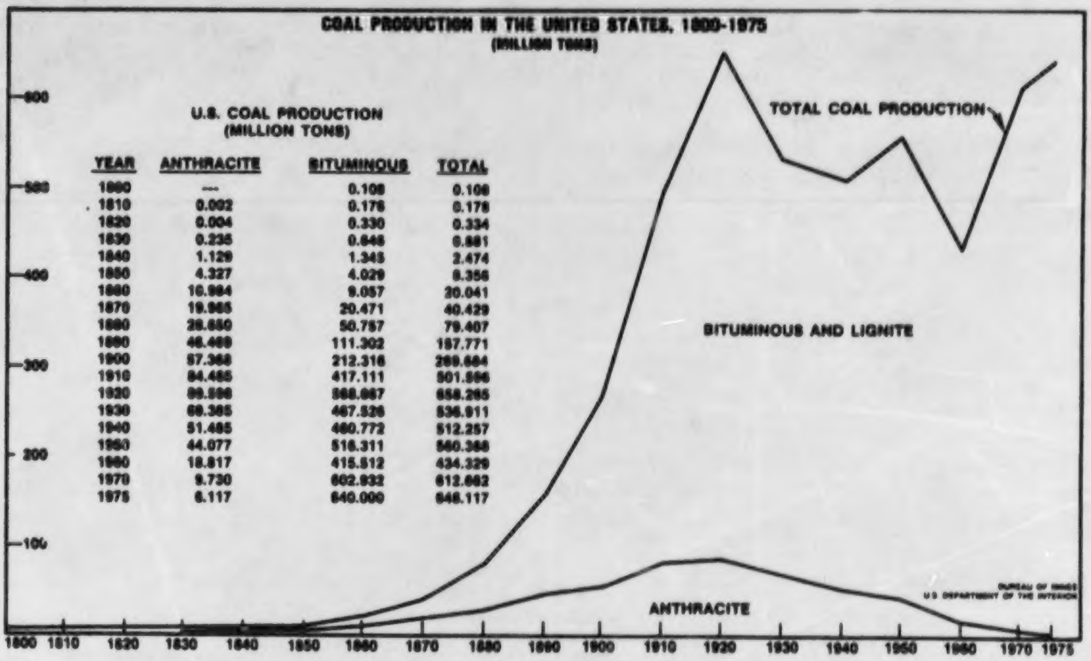
1734. Positive and negative electric charges were recognized.

1735. Brandt discovered cobalt.

1741. The centigrade temperature system was introduced by Celsius of Sweden.

1743. The water turbine was demonstrated.

1745. The Leyden jar was invented to store electrical charges.



U.S. COAL PRODUCTION
(MILLION TONS)

YEAR	ANTHRACITE	BITUMINOUS	TOTAL
1800	—	0.108	0.108
1810	0.002	0.176	0.178
1820	0.004	0.330	0.334
1830	0.235	0.646	0.881
1840	1.129	1.345	2.474
1850	4.327	4.029	8.356
1860	10.984	9.057	20.041
1870	19.958	20.471	40.429
1880	28.650	50.757	79.407
1890	46.469	111.302	157.771
1900	57.368	212.316	269.684
1910	84.485	417.111	501.596
1920	89.598	568.667	658.265
1930	69.385	467.526	536.911
1940	51.485	460.772	512.257
1950	44.077	516.311	560.388
1960	18.817	415.512	434.329
1970	9.730	602.932	612.662
1975	6.117	640.000	646.117

Figure 3.—Coal production in the United States in million tons, 1800–1975 (*8,9*).

1745. The first blast furnace was installed in Great Britain.

1747. Atmospheric electricity was discovered by Benjamin Franklin.

1748. The first coal mine was opened near Richmond, Va.

1751. Nickel was isolated by Axel Cronstedt of Sweden.

1752. The first lightning rod was installed by Benjamin Franklin.

1754. Andreas Sigismund, of Germany, proved aluminum to be a distinct earth metal.

1755. The first iron bridge was built in France.

1763. The first record of anthracite in the United States.

1764–79. Spinning machinery was developed in Great Britain.

1766. A five-ton copper boulder was discovered in the Lake Superior area.

1767. The first cast-iron railway track was installed in Great Britain.

1769. Anthracite coal was used in forges in Pennsylvania.

1770. A self-propelled, steam-driven gun carriage was constructed in France.

1771. Fluorine was discovered.

1774. Chlorine was discovered.

1775–1801. Machine tools were developed in Great Britain.

1775. Natural gas was discovered in the Ohio Valley.

1776. Cannons were cast at the furnaces at Warwick and Reading, Pa.

1776. Anthracite was shipped to the Continental Ordnance at Carlisle, Pa.

1777. The first iron boat was built in Great Britain.

1778. The first duplicating machine similar to modern offset printing equipment was invented in Great Britain.

1779–1848. Catalytic action was discovered by Berzelius of Sweden.

1779. The first rotating steam engine was built in Great Britain.

1779. The first factory machinery was driven by steam power in Great Britain.

1780. Iron making was established in every one of the 13 states.

1780. Native copper was mined at Santa Rita, N.M.

1781. Tungsten was identified by K.W. Scheele of Sweden.

1782. Tellurium was discovered by Muller von Richenstein of Germany.

1782. Hjelm isolated and named molybdenum.

Post-Revolutionary Period, 1783 to Date

1783. A process to prepare malleable platinum was patented in France.

1785. First textile machinery driven by steam power in Great Britain.

1785. Coulomb, of France, formulated the law of electron charges.

1789. Electrolysis was demonstrated in Holland.

1789. Uranium was discovered by Klaproth of Germany.

1789. Zirconium was discovered by Klaproth of Germany.

1790. Titanium was discovered by Gregor of Great Britain.

1790. The first commercial steamboat was launched by John Fitch on the Delaware River.

1790. The first battery was made by Volta of Italy.

1791. Galvani discovered the principle of bimetallic batteries.

1791. John Barber patented the gas turbine in Great Britain.

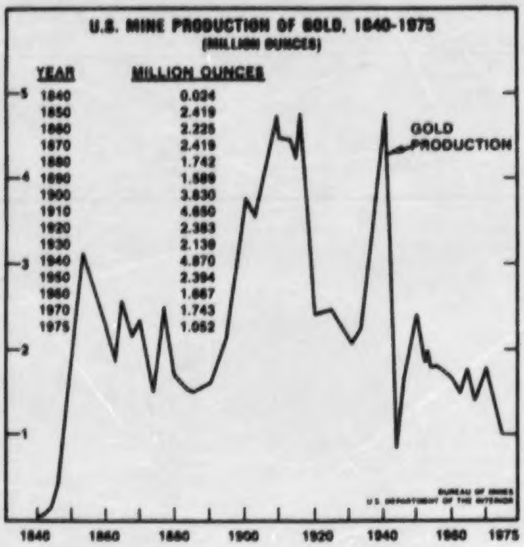


Figure 4.—U.S. mine production of gold in million ounces, 1840–1975 (*6,8,11*).

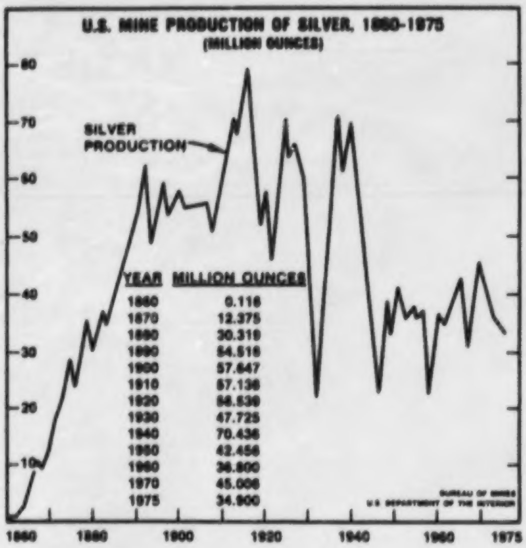
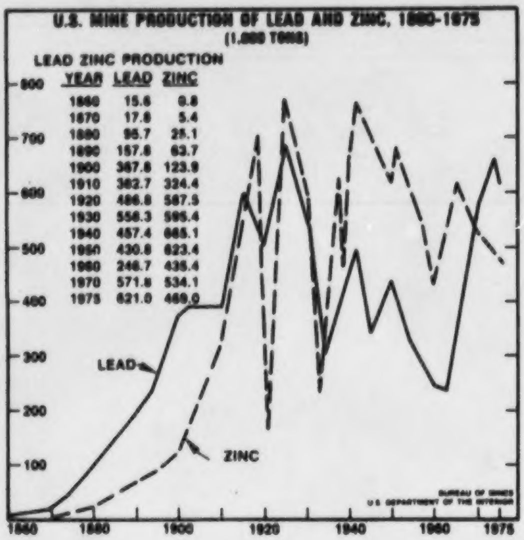


Figure 5.—U.S. mine production of silver in million ounces, 1860–1975 (*6,8,11*).

Time Capsule, 1776–1976 (Continued)

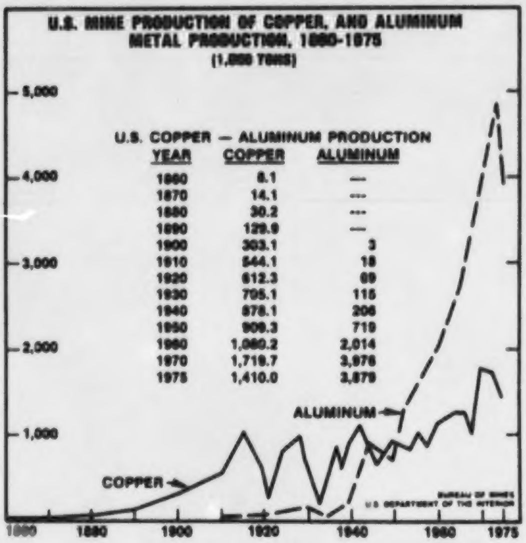
1793. Eli Whitney invented the cotton gin.
1793. Metric weights were introduced in France.
1794. Yttrium was discovered and named by Gadolin of Sweden.
1797. Beryllium was discovered by Vauquelin of France.
1797. Chromium was isolated by Vauquelin of France.
1798. A reverberatory lead smelting furnace was installed at Herculaneum near the Mississippi River.
1799. Electrotyping was discovered by Volta of Italy.
1800. The steam engine was used to operate a blast furnace.
1800. The electric battery was invented by Volta of Italy.
1800. Electroplating was demonstrated in Germany.
1801. Columbium was discovered by Charles Hatchett of Great Britain.
1801. Tantalum was discovered.
1802. The dry battery was invented by George Beherns.
1802. The electric arc was discovered by Sir Humphrey Davy of Great Britain.
1803. The first pure platinum was produced by Wollaston.
1803. A steam locomotive was built in Great Britain.
1804. Osmium and iridium were isolated and named by S. Tenant.
1804. The first steam-driven electric locomotive operated in Wales, Great Britain.
1804. Production of lead at Mine LaMotte (Missouri) during the previous 81 years totaled 8,000 tons.
1804. A steamboat in New Jersey was fitted with the first screw propeller.
1807. Lithium was discovered by Arfvedsen of Sweden.
1808. The first practical typewriter was built in Italy.
1809. The first steamboat operated in the open sea from New York to Philadelphia. Time required - 13 days.
1807. Davy discovered sodium by electrolysis.
1813. The first rock drill was invented.
1816. Baltimore, Md., was the first city in the United States to light streets with manufactured gas.
1817. Selenium was discovered by Berzelius of Sweden.
1817. Cadmium was isolated and named by Strohmeyer of Germany.
1817. First use of coke instead of charcoal for smelting at Plumsock, Pa.
1819. The first steamship crossed the Atlantic Ocean, from Savannah, Ga. to Liverpool, in 27 days. It was a paddle-wheel ship.
1820. Ampere discovered the magnetic effect of electricity.
1820. Oersted discovered the magnetic field around an electric conductor.
1820. The galvanometer was invented and named after Galvani of Italy.
1820. The electromagnet was discovered by Davis, of Great Britain; also by Oersted of Denmark.
1821. Michael Faraday, of Great Britain, demonstrated the electric motor.
1821. First natural gas well was drilled in Fredonia, N.Y.
1821. First natural gas was transported by hollow-log pipeline from Fredonia, N.Y.
1822. Thomas Seebeck discovered the principle of thermoelectricity.
1824. Berzelius, of Sweden, produced pure silicon and pure metallic zirconium.
1824. Sadi Carnot discovered the basic principle of thermodynamics in France.
1825. The first railroad locomotive was built at Hoboken, N.J.
1826. Ohn's Law was formulated.
1828. Thorium was discovered by Berzelius of Sweden.
1829. The electric transformer was invented by Joseph Henry of United States.
1829. The first steam yacht was built in Great Britain.
1830. Vanadium was discovered and named by Sefstrom of Sweden.
1830. Compressed air was used for tunneling in Great Britain.
1830. The steam hoist was developed.
1830's. McCormick invented the reaper and the steam-powered threshing machine. This was the beginning of the mechanized agricultural age.



LEAD ZINC PRODUCTION

YEAR	LEAD	ZINC
1860	15.6	0.8
1870	17.8	5.4
1880	95.7	25.1
1890	157.8	63.7
1900	367.8	123.9
1910	382.7	324.4
1920	486.8	587.5
1930	556.3	595.4
1940	457.4	665.1
1950	430.8	623.4
1960	246.7	435.4
1970	571.8	534.1
1975	621.0	469.0

Figure 6.—U.S. mine production of lead and zinc in thousand tons, 1860–1975 (*6,8,11*).



U.S. COPPER — ALUMINUM PRODUCTION

YEAR	COPPER	ALUMINUM
1860	8.1	—
1870	14.1	---
1880	30.2	---
1890	129.9	—
1900	303.1	3
1910	544.1	18
1920	612.3	69
1930	705.1	115
1940	878.1	206
1950	909.3	719
1960	1,080.2	2,014
1970	1,719.7	3,976
1975	1,410.0	3,879

Figure 7.—U.S. mine production of copper, and aluminum metal production, 1860–1975 (*6,8,11*).

1831. The first commercial steam turbine was built in the United States by William Avery.
1831. Faraday built the first electric generator.
1831. The first electric dynamo was invented in France.
1832. The water turbine was developed in France.
1832. The first railroad was built in the United States.
1833. Thomas Davenport invented the electric motor in the United States.
1833. Faraday suggested that the current is carried in an electrolyte by ions.
1833. Anthracite coal was used in metal production in the United States.
1834. The principle of semiconductors and transistors was recognized.
1835. Good gray forge iron was produced with coke.
1836. Daniell invented the wet cell.
1836. Joseph Henry Morse completed the first telegraphic device.
1837. The first electric motor was patented in Vermont.
1838. The induction coil was constructed by Grafton Page in the United States.
1839. A three-stage air compressor was patented.
1839. The first commercially successful photographic process was introduced by Daguerre of France.
1839. The first camera was marketed by Giroux of France.
1839. The first experimental electric locomotive was operated between Washington and Bladensburg.
1840. This date is regarded as the beginning of the Age of Electricity because the numerous discoveries by Galvani, Volta, Ampere, Ohm, Faraday, Franklin, Henry and others were put into practical use.
1841. John A. Roebling invented an improved method of drawing wire and spinning cables for bridges and hoisting.
1842. Coking coal was discovered in Pennsylvania.
1843. The first telegram service was installed in Great Britain.
1843. By this time the railroad trackage installed in the United States totaled 4,026. This increased to 93,262 miles by 1880; 258,238 miles by 1924; and 354,000 miles by 1973.
1843. First steam shovel excavator operated in Great Britain.
1843. The first artificial fertilizers (superphosphates) were sold in Great Britain.
1844. Artificial hydraulic cement was manufactured.
1844. Ruthenium was named and discovered by C. Claus.
1844. First prospecting rights for copper were issued in the Upper Peninsula, Michigan.
1845. Raw bituminous coal was first used in blast furnaces.
1845. Iron ore was discovered in the Lake Superior district.
1845. Copper production started in Upper Michigan. By 1895 production from this area totaled 129.3 million pounds.
1846. First rotary powered printing press installed in Philadelphia.
1846–49. Gold was discovered in the Black Hills of South Dakota, but not revealed by discoverers.
1847. First insulated electric cables were made in Great Britain.
1848. Flood lighting with electric arc lights was introduced in Great Britain.
1848. The first oil refinery was established in Great Britain.
1848. Discovery of gold in California.
1848. Gold was discovered by Russian mining engineers on the Kenai River, Alaska.
1848. First iron ore was smelted successfully in the Lake Superior district.
1849. The microscope was first used to study physical metallurgy.
1849. The compressed air rock drill was invented.
1849. The U.S. Department of the Interior was created.
1851. Overseas telegraph service by submarine cable was initiated in Great Britain.
1851. The first domestic sewing machine was manufactured in the United States by Singer. The first electrically driven machine was made in 1889.
1852. Gold was discovered in the Deer Lodge County area of Montana.
1853. The rotary cultivator was introduced.

Time Capsule, 1776–1976 (Continued)

1855. The first practical computer was built in Sweden.
1856. Synthetic coal tar dyes were developed.
1856. Michael Faraday produced the first aluminum electrolytically.
1857–71. Rail-mounted drill carriages, hydraulic-ram air compressors, and compressed air drills were used to drive the Mont Cenis tunnel in the Alps.
1857. The compressed air rock drill was developed in France.
1858. Atomic weights were pioneered by S. Canerizarro of Italy.
1858. The Comstock Lode was discovered in Nevada.
1859. Coking coal was used to smelt iron ore in Pittsburgh.
1859. The cathode ray tube was discovered.
1859. Designated as the birth of Colorado's mining industry. Gold was discovered at Clear Creek.
1859. Oil was discovered at Titusville, Pa. The first oil well was drilled.
1859–60. Intensive prospecting was carried on in the Colorado Rockies.
1860. Cold rolling of steel was developed at Pittsburgh.
1860. Cesium was discovered by Kirchhoff of Germany.
1860. An expedition was organized in San Francisco to prospect for gold in the Southwest. Gold was discovered near Pinos Altos, N.M.
1860. The first oil refinery was built near Titusville, Pa.
1860. Sir Henry Bessemer invented the Bessemer steelmaking process in Great Britain.
1860. First synthetic rubber was made.
1860. The first internal combustion engine was produced commercially in Italy.
1860's. The dry cell battery was developed.
1860–70. Extensive prospecting in the Southwest resulted in numerous mining operations and prospects in Arizona and New Mexico.
1860. Leadville, Colorado, was established.
1861. Rubidium was discovered by R.W. Bunsen of germany.
1861. About 5,000 prospectors were active on the South Fork of the Clearwater River in Idaho. By 1962 the number in the general area increased to about 20,000.
1861. Artificial refrigeration was demonstrated in Australia.
1862. Thallium was discovered by Sir William Crookes of Great Britain.
1863. Natural gas was used for industrial purposes at East Liverpool, Ohio.
1863. Angstrom developed the Angstrom unit to measure spectrum lines.
1863. The first self-propelled submarine was launched in France.
1863. The first motor car was driven by an internal combustion engine by Lenoir of Belgium.
1863. Reich and Richter isolated and named indium in Germany.
1864. First lode claims for silver were located at Butte, Montana. In 1878, the output of gold and silver in the area was valued at $1.2-million.
1864. Bacteria discovered by Pasteur in France.
1864. The open-hearth furnace was developed in France.
1864. The St. Joseph Lead Co. was organized to mine and smelt lead in Missouri.
1864. Gold-lead-silver mining started in the area of Utah near Salt Lake City.

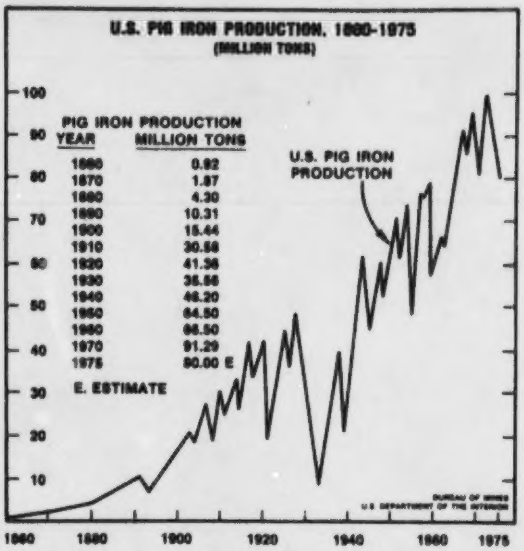


Figure 8.—U.S. pig iron production in million tons, 1860–1975 (*6*).

1865. The railroad tank car was developed to transport crude oil.
1865. The first company to distribute natural gas was formed at Fredonia, N.Y.
1865. The first oil pipeline was laid to transport oil 5 miles from Pithole City to the Oil Creek Railroad in Pennsylvania.
1866. The first thermosplastic material was made from nitrocellulose by Alexander Parkes of Great Britain.
1866. The first radio signalling system was operated in the United States.
1866. The Atlantic cable was installed.
1866. The first mining law applied to lode claims was passed.
1867. Helium was discovered.
1867. Dynamite was invented by Alfred Nobel.
1867. United States purchased Alaska from Russia.
1867. The tubular boiler was invented by Babcock and Wilcox.
1867. The first barbed wire was made in Ohio.
1868. First shipment of copper from Bingham Canyon, Utah.
1868. Gold production at Virginia City, Mont., totaled about $30 million.
1869. First diamond drill brought to Bonne Terre, Mo., from France.
1869. Mendeleev published the periodic table.
1869. The first transcontinental railroad was completed in the United States.
1869. Electrolytic refining was installed at South Wales, Great Britain.
1870. The Standard Oil Company of Ohio was formed by John D. Rockefeller and associates.
1870's. The magnetohydrodynamic principle of generating electricity was recognized.
1870's. The thermoelectric principle of generating electricity was discovered.
1871. Ingersoll Rand invented the rock drill.
1872. First mining law pertaining to placer claims was passed.

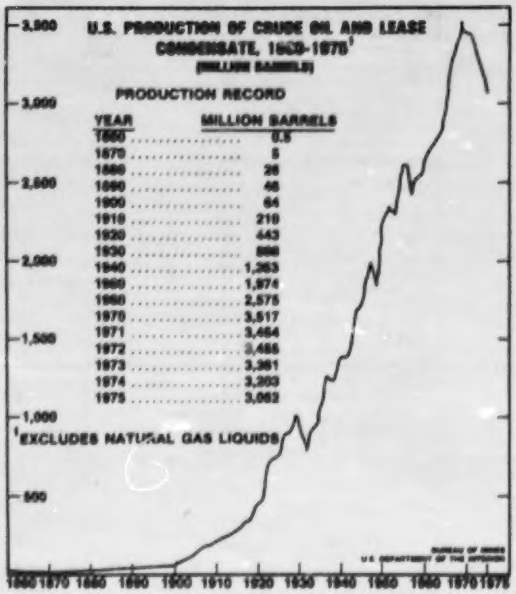


Figure 9.—U.S. crude oil and lease condensate production in million barrels, 1860–1975 (*8,9*).

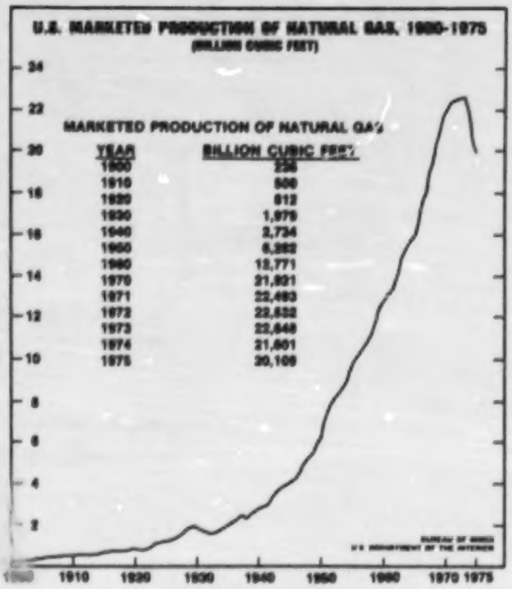


Figure 10.—U.S. marketed production of natural gas in billion cubic feet, 1900–1975 (*8,9*).

1872. The Mining Law of 1872 also specified local recording of claims, required assessment work, specified how surface boundaries were to be established, and granted apex rights.

1873. The zinc-mercury battery was developed.

1873. The effect of light on the selenium cell was discovered.

1873. The linotype was introduced.

1874. General Custer reports presence of gold in the Black Hills of South Dakota.

1874. The phase rule of metallurgy was formulated by Willard Gibbs.

1875. Gallium was first isolated by De Boisbaudran of France.

1875. The continuous compressed air brake was invented by George Westinghouse.

1875. The first battery-powered dental drill was operated.

1875–85. First principles of modern petroleum engineering and geology were established by the Pennsylvania Geological Survey.

1876. Scandium was discovered by Lars Nilson of Sweden.

1876. The telephone was demonstrated by Alexander Graham Bell.

1876. The Homestake mine was located in the Black Hills, S.D. The Homestake Mining Co. was organized in the following year.

1876. Liquid oxygen was produced in Switzerland.

1876. The gasoline engine was developed in Germany.

1877. The smelter was built at Leadville, Colo.

1877. The copper wealth near Bisbee, Ariz., was discovered.

1878. The first practical electric furnace was installed in Great Britain.

1878. The Crooke's tube was invented by Sir William in Great Britain.

1878. Thomas Edison discovered the thermionic electric generating principle.

1878. Ytterbium was discovered.

1878. Thulium was discovered.

1879. Radiotelegraphy was demonstrated in Great Britain.

1879. Thomas A. Edison invented the incandescent lamp.

1879. The U.S. Geological Survey was established.

1879–85. Numerous gold mining claims and prospects were operated in the Coeur d'Alene district of Idaho.

1879. First major oil pipeline was completed; 110 miles from Pithole City to Williamsport, Pa.

1880. Gold was discovered at Cripple Creek, Colo., by Robert Womack.

1880. A tunnel was bored with a pneumatic tunneler in Great Britain.

1880. The first electric passenger elevator was operated in Germany.

1880. The hydraulic rock drill was introduced.

1881. The generation of alternating current was patented in Europe by French and British inventors.

1881. The spindle-type cotton picking machine was invented by Angus Campbell.

1881. The Anaconda Silver Mining Co. was organized in the Butte area.

1881. The first hydroelectric power station was operated in Surrey, England.

1881. First incandescent street lights were installed in Great Britain.

1882. The first central station to supply electric power was installed in London, England. A second was installed in New York City. Both were built by Thomas A. Edison.

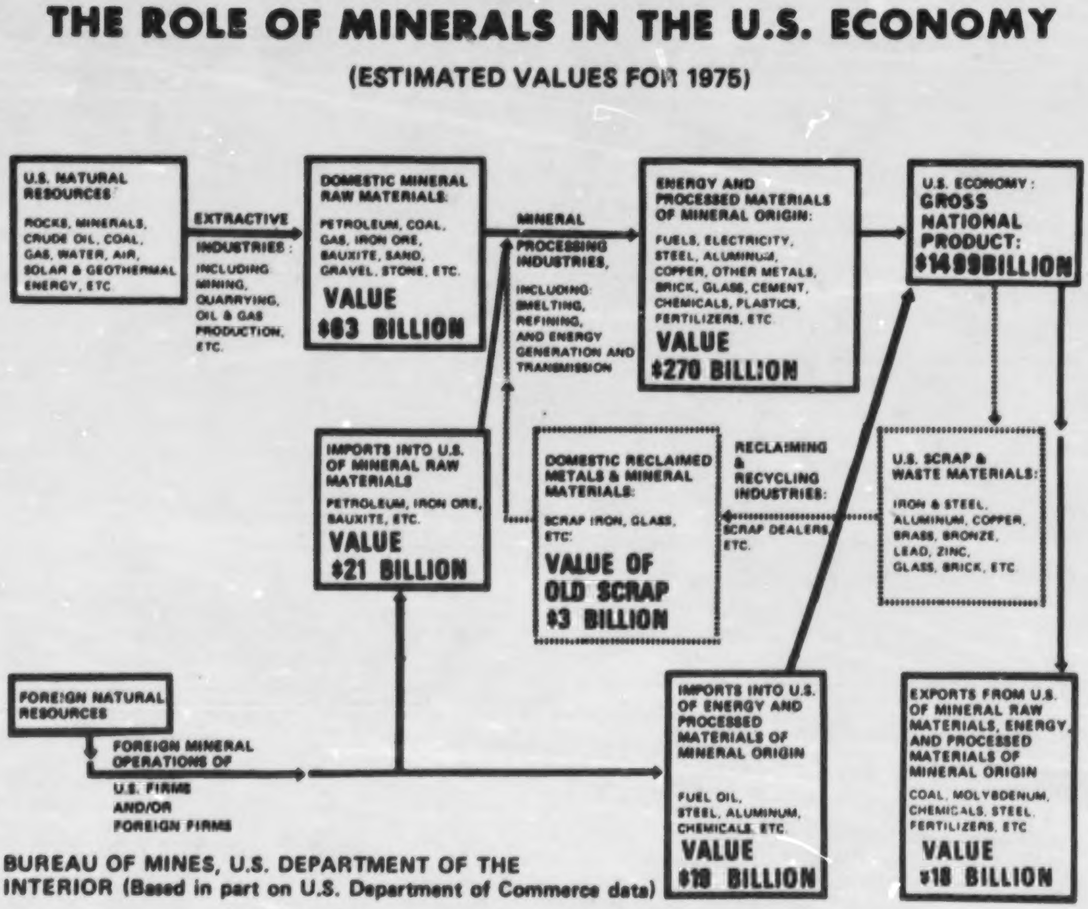
1882. A steel ocean liner was constructed in Great Britain.

1883. The first application of cryogenics was reported.

1883–87. Svamte Arrhenius, of Sweden, worked out the quantitative theory of ionization.

1883. The anticlinal theory for oil accumulation was confirmed by drilling.

1884. Sir Charles Parson built the multiple-stage steam turbine in Great Britain.

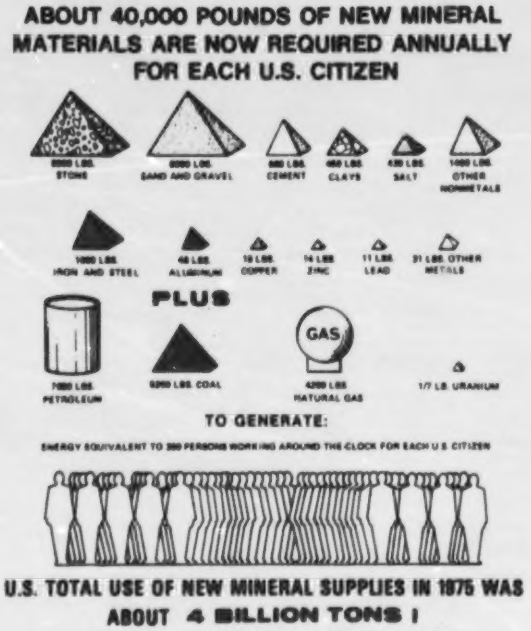

THE ROLE OF MINERALS IN THE U.S. ECONOMY
(ESTIMATED VALUES FOR 1975)
U.S. NATURAL RESOURCES
ROCKS, MINERALS, CRUDE OIL, COAL, GAS, WATER, AIR, SOLAR & GEOTHERMAL ENERGY, ETC.
EXTRACTIVE INDUSTRIES: INCLUDING MINING, QUARRYING, OIL & GAS PRODUCTION, ETC.
DOMESTIC MINERAL RAW MATERIALS:
PETROLEUM, COAL, GAS, IRON ORE, BAUXITE, SAND, GRAVEL, STONE, ETC.
VALUE $63 BILLION
MINERAL PROCESSING INDUSTRIES, INCLUDING: SMELTING, REFINING, AND ENERGY GENERATION AND TRANSMISSION
ENERGY AND PROCESSED MATERIALS OF MINERAL ORIGIN:
FUELS, ELECTRICITY, STEEL, ALUMINUM, COPPER, OTHER METALS, BRICK, GLASS, CEMENT, CHEMICALS, PLASTICS, FERTILIZERS, ETC
VALUE $270 BILLION
U.S. ECONOMY: GROSS NATIONAL PRODUCT: $1499BILLION
IMPORTS INTO U.S. OF MINERAL RAW MATERIALS
PETROLEUM, IRON ORE, BAUXITE, ETC.
VALUE $21 BILLION
DOMESTIC RECLAIMED METALS & MINERAL MATERIALS:
SCRAP IRON, GLASS, ETC.
VALUE OF OLD SCRAP $3 BILLION
RECLAIMING & RECYCLING INDUSTRIES:
SCRAP DEALERS, ETC.
U.S. SCRAP & WASTE MATERIALS:
IRON & STEEL, ALUMINUM, COPPER, BRASS, BRONZE, LEAD, ZINC, GLASS, BRICK, ETC
FOREIGN NATURAL RESOURCES
FOREIGN MINERAL OPERATIONS OF U.S. FIRMS AND/OR FOREIGN FIRMS
IMPORTS INTO U.S. OF ENERGY AND PROCESSED MATERIALS OF MINERAL ORIGIN
FUEL OIL, STEEL, ALUMINUM, CHEMICALS, ETC.
VALUE $18 BILLION
EXPORTS FROM U.S. OF MINERAL RAW MATERIALS, ENERGY, AND PROCESSED MATERIALS OF MINERAL ORIGIN
COAL, MOLYBDENUM, CHEMICALS, STEEL, FERTILIZERS, ETC
VALUE $18 BILLION

BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR (Based in part on U.S. Department of Commerce data)

Figure 11.—The role of minerals in the U.S. economy based on estimated values for 1975 (*13*).

Time Capsule, 1776–1976 (Continued)

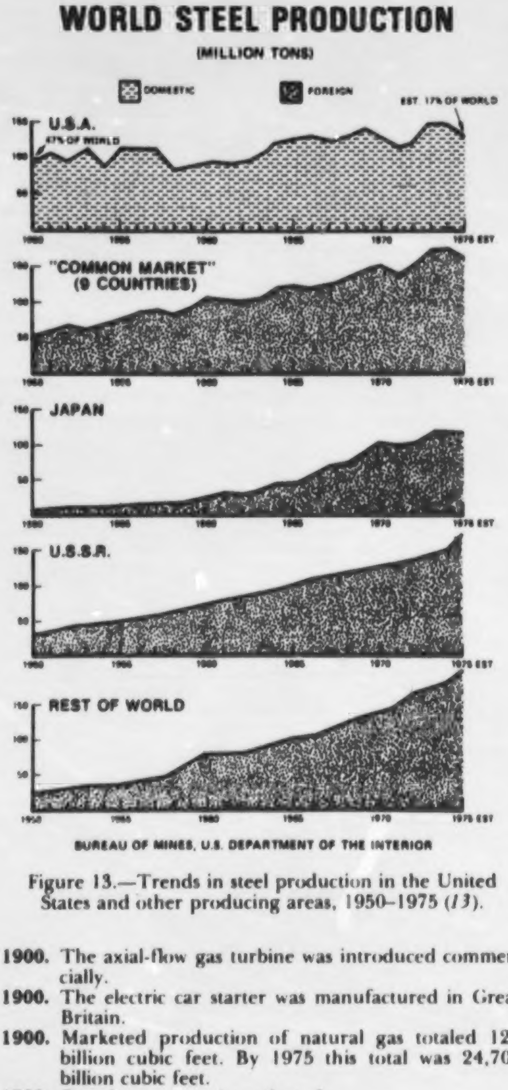
1885. W.A. Clark opened the United Verde mine in Arizona.
1885. Petroleum cracking was developed in the United States.
1885. The Bunker Hill mine was discovered in Idaho.
1885. The first film motion picture images were produced in France by Le Prince. He applied for a U.S. patent in 1886.
1885. The first motorcycle was patented in Germany.
1885. Eastman invented a machine to make photgraphic paper in rolls.
1886. Westinghouse demonstrated the practicability of alternating current energy in Massachusetts.
1886. Hall, of United States, and Heroult, of France, discovered the electrometallurgical process of producing aluminum independently.
1886. The linotype was used to set type for the New York Tribune.
1886. Winkler, of Germany, isolated and named germanium.
1887. The Bunker Hill and Sullivan Mining & Concentrating Co, was organized in Idaho.
1887. The first electric heater was patented.
1887. Steel was first used in pipelines.
1888. The principle of radar was discovered.
1888. Manganese steel was produced by Robert Hadfield.
1889. The Pelton water turbine was patented in the United States.
1889. An electric oven was built in Switzerland.
1890. Gold strike at Cripple Creek, Colorado.
1890's. The electrochemical process was developed in the United States.
1890's. Marconi developed first radio sending equipment.
1890. First petrol-driven motor boat was built in Germany.
1890. The first compression-ignition engine was developed commercially by Akroyd-Hornsby in Great Britain.
1890. The aluminum saucepan was manufactured.
1891. The first high-pressure, long-distance pipeline was installed to transport oil 120 miles from Greentown, Ind., to Chicago, Ill.
1891. Motion pictures were demonstrated publicly in West Orange, N.J.
1892. First concrete road was built in Ohio.
1892. First long-distance telephone call completed from New York to Chicago.


ABOUT 40,000 POUNDS OF NEW MINERAL MATERIALS ARE NOW REQUIRED ANNUALLY FOR EACH U.S. CITIZEN
LBS. STONE
LBS. SAND AND GRAVEL
LBS. CEMENT
LBS. CLAYS
LBS. SALT
LBS. OTHER NONMETALS
LBS. IRON AND STEEL
LBS. ALUMINUM
LBS. COPPER
14 LBS. ZINC
11 LBS. LEAD
21 LBS. OTHER METALS
PLUS
LBS. PETROLEUM
LBS. COAL
GAS
LBS. NATURAL GAS
1/7 LB. URANIUM
TO GENERATE:
ENERGY EQUIVALENT TO PERSONS WORKING AROUND THE CLOCK FOR EACH U.S. CITIZEN
U.S. TOTAL USE OF NEW MINERAL SUPPLIES IN 1975 WAS ABOUT 4 BILLION TONS!

BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR

Figure 12.—Per capita mineral consumption in the United States in pounds for 1975 (*13*).

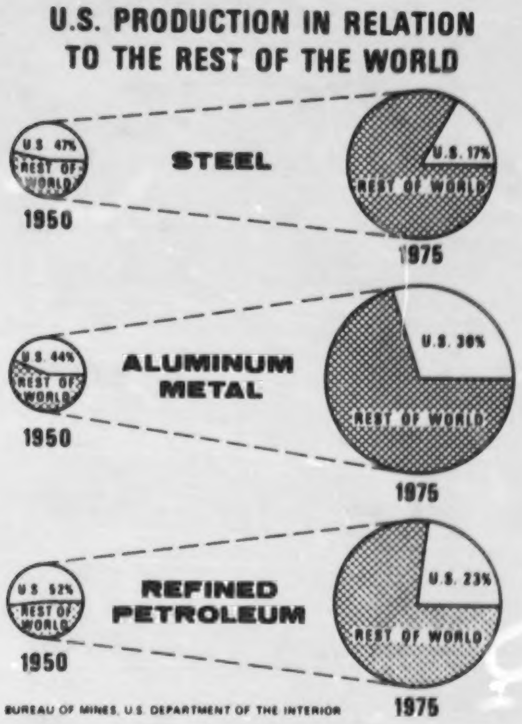
1892. First gasoline-powered automobile was built in the United States.
1892. The diesel engine was patented.
1894. Argon was discovered.
1894. G.J. Stoney proposed the name "electron" for negative electrical charges.
1894. The first practicable method of radio communications was developed by Marconi of Italy.
1894. The first oilfield was developed near Santa Barbara, Calif.
1894. Kerosine was exported to China by Standard Oil Co.
1894–97. J.J. Thompson demonstrated the principle of the cathode-ray tube.
1895. The Anaconda company was reorganized to form the Anaconda Copper Mining Co.
1895. The first regular motorbus passenger service was started in Germany.
1895. First pneumatic motor car tires were made by Michelin of France.
1895. The Baltimore and Ohio Railroad started the first electric mainline service.
1895. The first four delivery wagons, powered with imported Akroys-Hornsby engines, were built in Brooklyn, N.Y.
1896. Daimler built the first motor truck in Germany.
1896. Becquerel, of France, discovered radioactivity.
1897. Thomson, of Great Britain, discovered the electron.
1898. Viscose rayon was made in Great Britain.
1898. 33,000 gold seekers invaded the Klondike area of Alaska.
1898. Radium was discovered by Marie and Pierre Curie of France.
1899. The electric arc furnace was operated in France.
1899. The spark plug was manufactured in Great Britain.
1899, Actinium was discovered in France.



BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR

Figure 13.—Trends in steel production in the United States and other producing areas, 1950–1975 (*13*).

1900. The axial-flow gas turbine was introduced commercially.
1900. The electric car starter was manufactured in Great Britain.
1900. Marketed production of natural gas totaled 127 billion cubic feet. By 1975 this total was 24,700 billion cubic feet.
1900. Cosmic rays were investigated.
1901. Solar energy was used to power a steam engine.
1901. A discovery well at Spindletop near Beaumont, Texas, initiated the first salt dome production of oil.
1901. Motor oil was marketed by Mobil oil Co.
1901. First use of rotary drilling equipment at Spindletop oilfield in Texas.
1902. The first satisfactory coal face conveyor was operated in the United States.
1902. The agricultural tractor was demonstrated in Great Britain.
1902. The electrical rectifier was discovered by Peter Cooper-Hewitt in the United States.
1902. The first all-metal car body of aluminum was manufactured in Great Britain.
1903. The Utah Copper Company was organized. Copper production started in 1907.
1903. Orville and Wilbur Wright made the first heavier-than-air flight at Kitty Hawk, N.C.

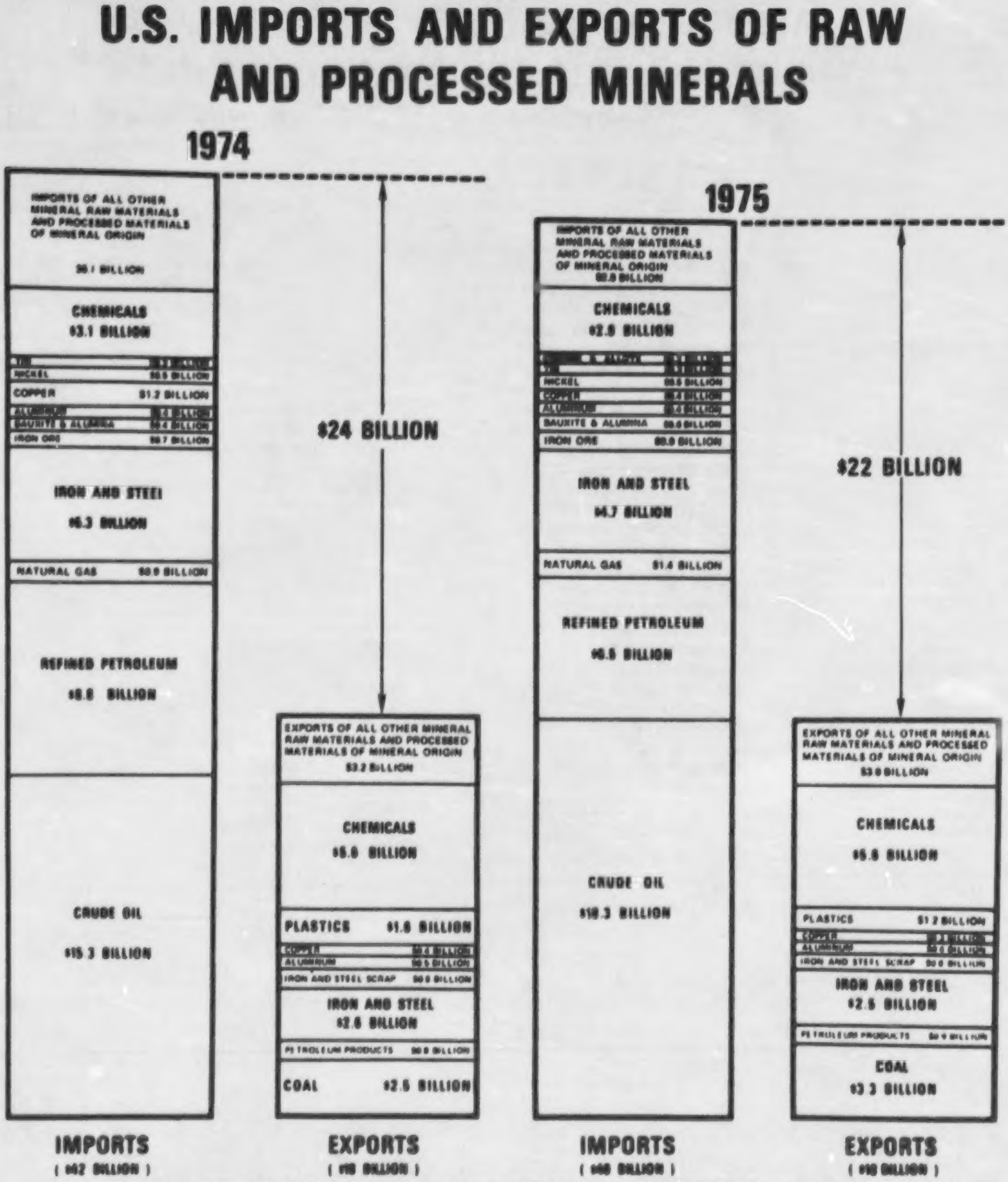


BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR

Figure 14.—U.S. and rest-of-world production of steel, aluminum, and petroleum, 1950 and 1975 (*13*).

Time Capsule, 1776–1976 (Continued)

1903. A 5,000-kw steam turbine was installed to generate electricity.
1903. The first commercial plant to process natural gas was installed at Sistersville, W. Va.
1904. Italian engineers drilled a steam well to operate a small turbine.
1904. The first electronic vacuum tube was made.
1904. The first steam-powered tractor crawler was operated in California.
1904. The first mass-produced motor car (more than 10 per week) was produced by Olds of Detroit.
1905. Einstein first propagated the theory of relativity.
1905. The first gasoline pump was installed at Ft. Wayne, Ind.
1906. The first radio broadcast was conducted at Brant Rock, Mass.
1906. The first pneumatic tires were used on aircraft in a test flight in France.
1906–07. First aircraft were manufactured in France and Great Britain.
1906. The first electrically operated loudspeaker was developed in New York.
1907. Household detergents were manufactured in Germany.
1907. De Forest invented the vacuum tube in the United States.
1908. A diesel-powered submarine was launched in Great Britain.
1908. First discovery of oil in the Middle East area, in Iran.
1909. The first military aircraft used in the United States.
1909. Bakelite was invented in Belgium.
1909. The first natural gas processing plant west of the Mississippi River was installed in Oklahoma.
1910. Neon lighting was developed in France.
1910. The Bureau of Mines, U.S. Department of the Interior, was established.
1910. First onshore drilling for oil in water in Louisiana.
1911. First airmail flown in India. 6,000 letters, 5 miles.
1911. E. Rutherford demonstrated that the positive charge of an atom is concentrated in the nucleus.
1911. First successful use of flotation in the United States on zinc-lead ore at Butte, Montana.
1911–12. Vitamins were discovered.
1912. First diesel locomotive was built in Switzerland.
1912. The first stainless steel was cast in Great Britain.
1912. X-ray analysis of minerals was demonstrated.
1913. First electric refrigerator for domestic use was manufactured in Chicago.
1913. Niels Bohr, of Denmark, solved the problem of the hydrogen atom.
1913. The first bomber aircraft was built in Great Britain.
1913. The first diesel-electric railcar was operated in Sweden.
1913. The thermal cracking process was patented to increase yield and quality of gasoline from petroleum.
1913. The first public address system was used in Oklahoma.
1914. The first passenger service airline started in the United States, from St. Petersburg to Tampa, Fla.
1914. Assembly-line production was started on the Model T by Henry Ford.
1915. Low-cost, high-tonnage gold mining started at Juneau, Alaska.
1915. Inspiration Consolidated Copper Co. built a 14,400 tpd mill to treat ore by flotation.
1916. First nitrogen fertilizer manufacture in Great Britain.
1918. The nation's largest gas field was discovered in the Texas Panhandle.
1918. The first fully-automatic oil burner was installed.
1919. The transmutation of elements was achieved by Sir Ernest Rutherford.
1920. The Mineral Leasing Act of 1920 was passed by Congress.
1922. Tetraethyl lead was developed for the internal combustion engine.
1922. First use of geophysical instruments for oil exploration.
1923. Mechanical coal loading equipment was installed to replace hand loading.
1923. Hafnium was discovered.
1923. The first successful television unit was built.
1923. The first cross-continent flight was made nonstop in the United States. Flying time was 27 hours.
1923. The first continuous hot-sheet rolling mill was operated in Ashland, Ky.
1924. The first round-the-world flight was completed by U.S. pilots; 57 stops.
1925. Rhenium was detected in platinum ores.
1925. The Society for Space Travel was organized in Germany, giving impetus to the development of rockets, including the V-2, in 1932–37.
1925. Petroleum was made synthetically from coal in Europe.
1925. The first commercial diesel-electric locomotive was built.
1926. The selenium rectifier was introduced.



BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR (data from Bureau of the Census)

Figure 15.—Imports and exports of raw and processed materials in the United States for 1974 and 1975 (*13*).

1927. The first low-definition image was sent by an electronic television system by Farnsworth in Los Angeles.

1927. The transatlantic telephone service was started from London to New York City.

1928. The first television receiver was produced commercially by the Daven Corp. of New Jersey.

1929. First magnetic tape recorder was built in Germany.

1929. Electric logging equipment was first used in oil wells.

1930. Wrought iron was produced by a continuous process in Pennsylvania.

1930's. The tungsten carbide bit was developed in Germany.

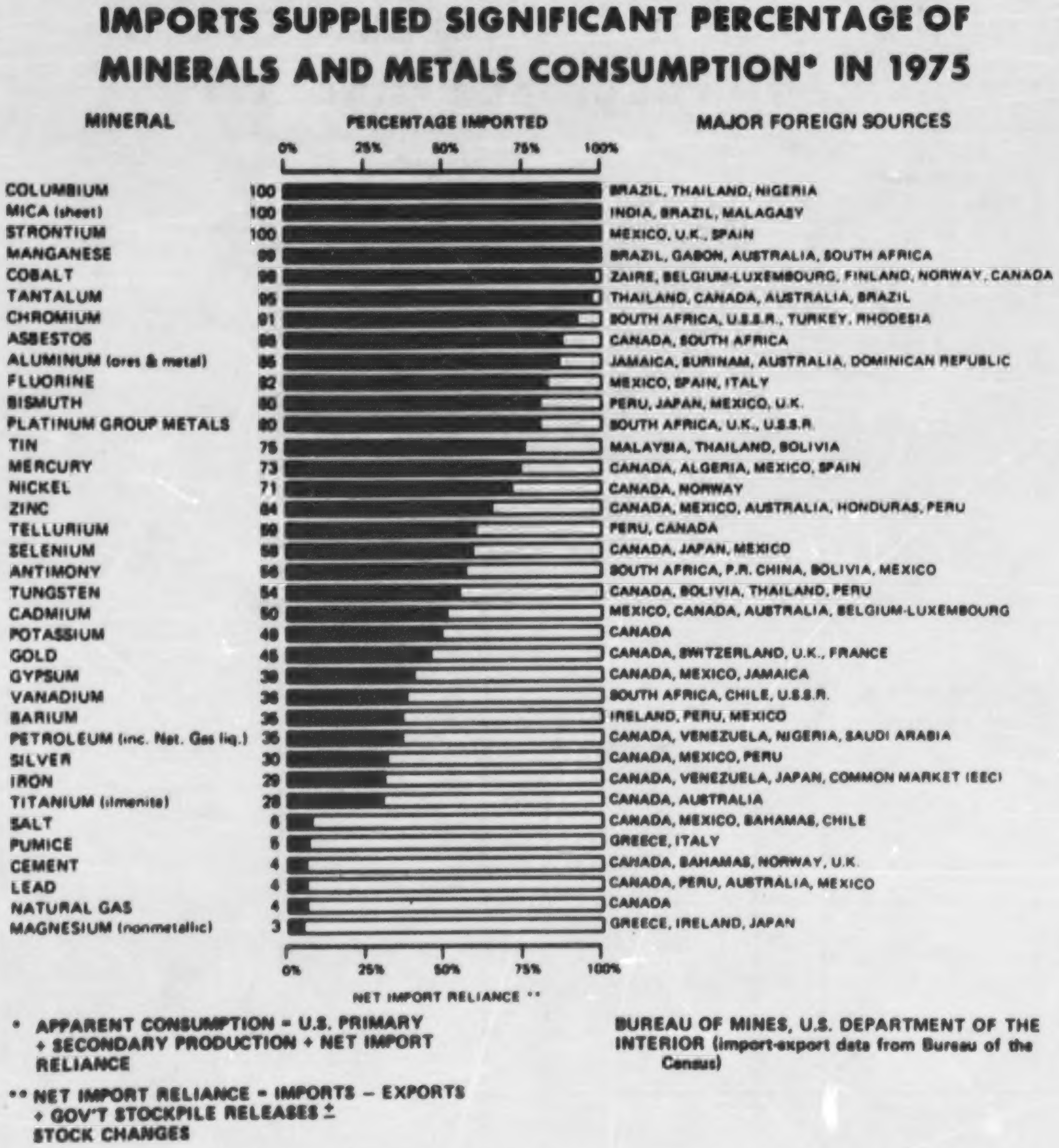
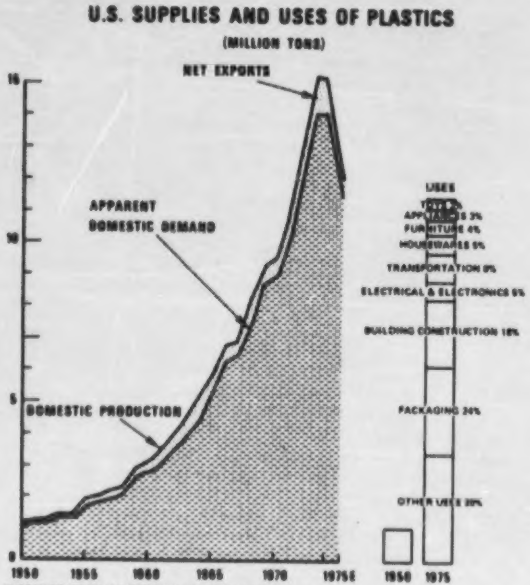


Figure 16.—Percentage of minerals and metals consumption supplied by U.S. imports in 1975 (*13*).

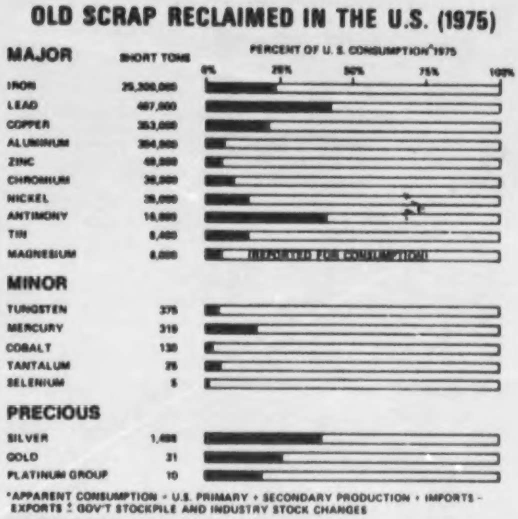
Time Capsule, 1776–1976 (Continued)

1930. The largest U.S. oilfield was discovered in East Texas.
1931. Artificial rubber, neoprene, was produced in the United States.
1932. The first fission of the nucleus of the atom was achieved by John Cockroft.
1933. The first radar equipment was developed in Germany.
1933. The first solo round-the-world flight was completed by Wiley Post of the United States.
1935. The first ship was fitted with radar in Germany.
1936. Fluorescent lighting was introduced by General Electric.
1937. The flying boat was inaugurated by British Imperial Airways, Ltd.
1937. Nylon was developed by DuPont.
1937. Catalytic cracking was introduced in the U.S. petroleum industry.
1938. Underground coal was gasified commercially in Russia.
1938. The first offshore field was developed in Louisiana.



BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR (from data by U.S. International Trade Commission, U.S. Department of Commerce and Modern Plastics)

Figure 17.—Old scrap recovered in the United States as percent of consumption, 1975 (*13*).



*APPARENT CONSUMPTION = U.S. PRIMARY + SECONDARY PRODUCTION + IMPORTS - EXPORTS ± GOV'T STOCKPILE AND INDUSTRY STOCK CHANGES

**INCLUDES EXPORTS

BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR

Figure 18.—U.S. supplies of plastic are heavily dependent upon petrochemicals and other minerals (*13*).

1939. Nuclear fission was demonstrated in Germany by Prof. Otto Hahn.

1939. E.O. Lawrence was awarded the Nobel Prize for development of the cyclotron.

1939. The first turbojet flight was made in Germany.

1939. The first transatlantic airline service was started by Pan American Airways.

1939. Polythene was manufactured in Great Britain.

1940. The first four-wheel drive Jeep was built for the U.S. Army.

1942. Fermi and coworkers produced the first man-made chain reaction at the University of Chicago.

1942. The Loran navigation system was developed in Great Britain.

1942. The first pure compound of plutonium was prepared at the University of California.

1943. Taconite ore was successfully treated by E.W. Davis in Minnesota.

1945. The first atomic bomb was exploded in the United States.

1946. The ENIAC, first electronic computer, was installed by the U.S. Ordnance. It weighed 30 tons and contained 18,000 vacuum tubes and 1,500 relays.

1946. The Bureau of Land Management was formed out of the General Land Office and the Grazing Service.

1946. The first all-electric digital computer was operated at Pennsylvania University.

1946. United Nations established an Atomic Energy Commission.

1947. The modern scintillation counter was introduced to detect and measure radioactivity.

1947. The first offshore well out of sight of land was drilled off the Louisiana Coast.

1947. The Mineral Leasing Act for Acquired Lands was passed.

1947. The transistor was invented. Beginning of the use of solid state devices in the electrical field.

1947. The microwave oven was built by Raytheon.

1948. The Germanium rectifier was announced in the United States.

1949. The discovery of uranium ore at Haystack Butte, N.M., triggered the uranium rush, the largest prospecting boom in the history of the United States.

1950's. Extensive work on the research and development of magnetohydrodynamic (MHD) power generation was started in the United States. Similar work was undertaken in Russia and Japan.

1950. The Xerox duplicating machine was manufactured.

1951. The electronic computer was manufactured.

1951. The first hydrogen bomb was tested in New Mexico.

1951. Sir J.D. Cockcroft and E.T. Walton were awarded the Nobel Prize in Physics for transmutation of the atomic nucleus.

1952. Jet aircraft was introduced in Great Britain.

1952. The United States exploded the first hydrogen bomb at Eniwetok Atoll in the Pacific Ocean.

1953. The first turbo-prop aircraft was put in service in Great Britain.

1953. Underground coal was gasified in Alabama.

1953. Russia exploded an experimental hydrogen bomb.

1954. The first soft-ground boring machine (mole) was used.

1954. High-voltage direct-current power transmission (20 megawatts) was installed in Sweden.

1954. The basic oxygen furnace (BOF) was introduced in the United States.

1954. The first nuclear-powered submarine, the Nautilus, was built at Groton, Mass. It traveled 69,138 miles on the first fueling.

1954. The second and third hydrogen bombs were exploded at Eniwetok Atoll.

1954. The first atomic power station (5,000 KW) was established near Obninsk, Russia.

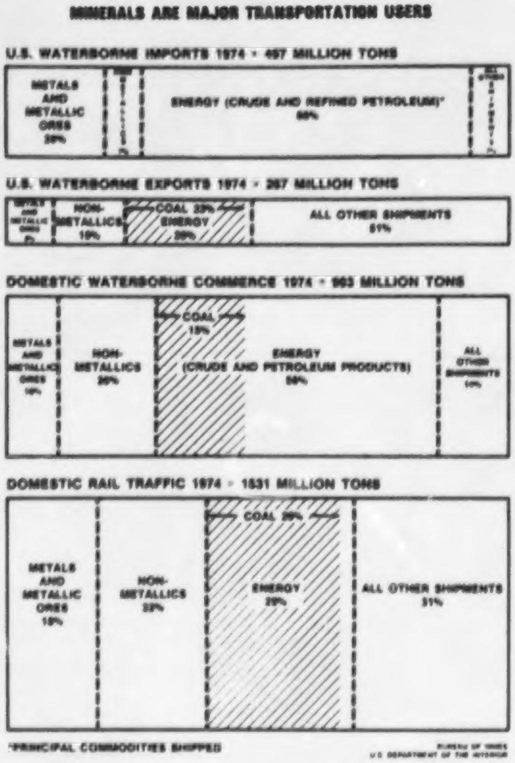


Figure 19.—Tonnages of minerals transported by rail and water, including imports and exports, 1974 (*13*).

Time Capsule, 1776–1976 (Continued)

1955. The Multiple Surface Use Act was passed by Congress.

1955. The first Hovercraft was developed in Suffolk, Great Britain.

1956. The first large-scale (90,000 KW) atomic power station was completed at Calder Hall, Great Britain.

1956. The neutrino atomic particle was detected.

1957. The Wankel rotary engine was designed in Germany.

1957. The first commercial atomic power plant was built at Shippingport, Pa.

1957. The portable electric typewriter was marketed.

1957. The first manned spaceflight was attempted by Ledovski, of Russia, but it was unsuccessful.

1957. Sputnik I was launched by Russia. The beginning of the space race.

1958. Transatlantic jet service was started.

1959. Russia launched the first spacecraft (the Luna II) to land on the Moon.

1960's. The reversible pump turbine was developed for pumped-storage power generation.

1960. A 12.5 megawatt geothermal steam plant delivered power in the United States. By 1975 installed capacity for geothermal power was 600 megawatts.

1960. The first nuclear-powered aircraft carrier was launched in the United States.

1961. The first successful manned space flight was completed in Russia by Gagarin.

1962. The first television communications satellite was launched in the United States.

1962. The first interplanetary space shot, the Mariner II was launched in the United States.

1963. A 60.9-megawatt liquid-metal, fast-breeder reactor was operated in Michigan.

1964. The Public Land Law Review Commission was established. Its report of recommendations was released in 1970.

1966. Five research teams investigated electrogasdynamic (EGD) power generation methods in the United States.

1967. A high-temperature, gas-cooled reactor (HTGR) began operations at the Peach Bottom plant in Pennsylvania.

1967. A team of 23 natural gas utilities undertook a $20 million research program to develop a natural gas fuel cell.

1969. The landing of Neil Armstrong and Edwin Aldrin of the Apollo XI spacecraft on the Moon was televised to the Earth.

1970. The first supersonic aircraft to fly was developed in Russia.

1970. The first extra high voltage (EHVC) direct current installation (400 kilovolts) was placed in service from northern Oregon to southern California.

1970. A 275-mile pipeline to deliver coal from Black Mesa, Arizona, to the Mohave power plant in California was completed at a cost of $35 million.

1970's. Soviet engineers operated the first open-cycle magnetohydrodynmanic power plant with an appreciable output.

1972. Landsat-1, formerly called ERTS-1, was launched in the United States to transmit satellite imagery to the Earth.

1973. The Arab oil embargo was imposed on the United States.

1974. Construction started on a unique 48-inch, 800-mile pipeline from Prudhoe Bay to Valdez, Alaska.

1974. Federal lands were opened to the development of geothermal power.

1975. The Ocean Mining Administration was established by the United States.

Because of lack of space, the foregoing chronology feathers out with some important fuel and energy developments—the most important commodity of the modern economies.

ORGANIZATION, DEFINITIONS, AND METHODOLOGY OF MINERAL FACTS AND PROBLEMS COMMODITY CHAPTERS

Basic Outline of the Commmodity Chapters

Commodity chapters are structured to follow the same general outline with additions or deletion of topics as may be necessary for specialized commodities. The general outline is as follows:

- Industry structure
  - Background
  - Size and organization
  - Geographic distribution
  - U.S. and world productive capacity, 1973, 1974, and 1980.
- Reserves and resources
  - U.S. and world, including table
  - Geology
- Uses
- Technology
  - Exploration and development
  - Mining
  - Processing
  - Products for trade and industry
  - Current research and applications
- Supply-demand relationships
  - Components of supply
    - Mine production
    - Imports of ore and concentrates
    - Imports of metal or refined products
    - Stocks
    - Old scrap
  - U.S. and world production
  - U.S. and world consumption
  - World trade
  - Secondary sources or recycling
  - Substitutes
- Byproducts and coproducts
- Strategic considerations
- Economic factors and problems
- Operating factors and problems
- Outlook
  - Demand
    - Forecasts for 1985 and 2000
    - Contingency forecasts, 1985 and 2000
    - End-use trends
    - Cumulative requirements to 2000
  - Supply
    - U.S. and world resources
    - Forecast production for United States to 1985 and 2000
      - 20-year trend projection
      - Contingency-type forecast
  - Possible supply-demand changes
  - Possible technological progress
  - Sources of current information
    - U.S. Bureau of Mines publications
    - Other sources

Mineral Resource Classification System (*18*)

Unless otherwise specified, the following mineral resources classification system of the Bureau of Mines and the U.S. Geological Survey as published in Geological Survey Bulletin 1450–A was used in the "Reserves-Resources" sections of the commodity chapters:

GENERAL DEFINITION OF MINERAL AND ENERGY RESOURCES

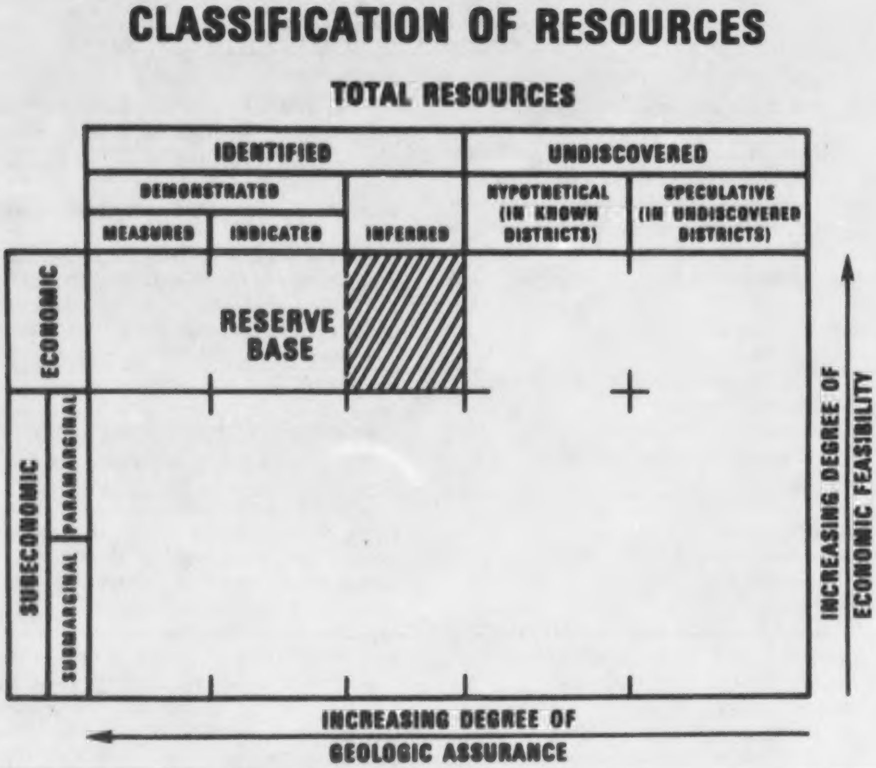
The dictionary definition of resource "something in reserve or ready if needed" has been extended for mineral and energy resources to comprise all materials surmised to exist having present or future values. In geologic terms a mineral or energy resource is a concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is currently or potentially feasible. Material classified as a reserve is that portion of an identified resource producible at a profit at the time of classification.

Total Resources are materials that have present or future value and comprise identified or known materials plus those not yet identified, but which on the basis of geologic evidence are presumed to exist.

PHILOSOPHIC BASIS FOR A RESOURCE CLASSIFICATION

Public attention usually is focused on current economic availability of mineral or energy materials (reserves). Long-term public and commercial planning, however, must be based on the probability of geologic identification of resources in as yet undiscovered deposits and of technologic development of economic extraction processes for presently unworkable deposits. Thus, all the components of Total Resources must be continuously reassessed in the light of new geologic knowledge, of progress in science, and of shifts in economic and political conditions.

Another requirement of long-term planning is the weighing of total or multi-commodity resource availability against a particular need. To achieve this the general classification system must be uniformly applicable to all commodities


CLASSIFICATION OF RESOURCES
TOTAL RESOURCES
IDENTIFIED
UNDISCOVERED
DEMONSTRATED
MEASURED
INDICATED
INFERRED
HYPOTHETICAL (IN KNOWN DISTRICTS)
SPECULATIVE (IN UNDISCOVERED DISTRICTS)
ECONOMIC
RESERVE BASE
SUBECONOMIC
PARAMARGINAL
SUBMARGINAL
INCREASING DEGREE OF ECONOMIC FEASIBILITY
INCREASING DEGREE OF GEOLOGIC ASSURANCE

SOURCE: BUREAU OF MINES

Figure 20.—Classification of resources as published in U.S. Geological Survey Bulletin 1450–A (*18*).

so that data for alternate or substitute commodities can be compared.

To serve these planning purposes Total Resources are classified both in terms of economic feasibility and of the degree of geologic assurance. The factors involved are incorporated in figure 20 to provide a graphic classification of Total Resources.

General guides for the use of this classification system are as follows:

1. Resource categories and definitions in the classification, as specified in the glossary, should be applicable to all naturally occurring concentrations of metals, nonmetals, and fossil fuels. The categories may be subdivided for special purposes.
2. Definitions may be amplified, where necessary, to make them more precise and conformable with accepted usage for particular commodities or types of resource evaluations.
3. Quantities and qualities may be expressed in a variety of terms and units to suit different purposes, but must be clearly stated and defined.

GLOSSARY OF RESOURCE TERMS

Resource.—A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.

Identified resources.—Specific bodies of mineral-bearing material whose location, quality, and quantity are known from geologic evidence supported by engineering measurements with respect to the demonstrated category.

Undiscovered resources.—Unspecified bodies of mineral-bearing material surmised to exist on the basis of broad geologic knowledge and theory.

Reserve.—That portion of the identified resource from which a usable mineral and energy commodity can be economically and legally extracted at the time of determination. The term *ore* is used for reserves of some minerals.

The following definitions for measured, indicated, and inferred are applicable to both the Reserve and Identified-Subeconomic resource components.[1]

Measured.—Reserves or resources for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geologic character is so well defined that size, shape, and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits which are stated, and no such limit is judged to be different from the computed tonnage or grade by more than 20 percent.

Indicated.—Reserves or resources for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout.

Demonstrated.—A collective term for the sum of measured and indicated reserves or resources.

Inferred.—Reserves or resources for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred reserves or resources should include a statement of the specific limits within which the inferred material may lie.

Identified-Subeconomic.—Resources that are not Reserves, but may become so as a result of changes in economic and legal conditions.

Paramarginal.—The portion of Subeconomic Resources that (1) borders on being economically producible or (2) is not commercially available solely because of legal or political circumstances.

Submarginal.—The portion of Subeconomic Resources which would require a substantially higher price (more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology.

Hypothetical resources.—Undiscovered resources that may reasonably be expected to exist in a known mining district under known geologic conditions. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as a Reserve or Identified-Subeconomic resource.

Speculative resources.—Undiscovered resources that may occur either in known types of deposits in a favorable geologic setting where no discoveries have been made, or in as yet unknown types of deposits that remain to be recognized. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as Reserves or Identified-Subeconomic resources.

AREAS OF RESPONSIBILITY AND OPERATIONAL PROCEDURES

U.S. Bureau of Mines.—The Bureau appraises, analyzes, and publishes reserve estimates from base data supplied by the mineral and energy materials industry, the U.S. Geological Survey, and other governmental agencies. The Bureau judges commodity recoverability on existing economic and legal factors.

U.S. Geological Survey.—The Survey appraises, analyzes, and publishes estimates of Total Resources. It reports such measurable parameters of significance to resource evaluation as location, quality, quantity, and situation of Identified resources.

Annual Resource Summation.—The U.S. Bureau of Mines and U.S. Geological Survey will confer and agree annually on estimates in all of the resource categories defined above. These data will be in Bureau or Survey publications and will be available for inclusion in the Secretary's Annual Report required by the Mining and Minerals Policy Act of 1970.

Ad Hoc Joint Conferences.—The Directors will convene ad hoc joint work groups to resolve problems in the resource area.

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[1] The terms proved, probable, and possible (used by the industry and economic evaluations of ore in specific deposits or districts) commonly have been used loosely and interchangeably with the terms measured, indicated, or inferred (used by the Department of the Interior mainly for regional or national estimates). The terms "proved" and "measured" are essentially synonymous. The terms "probable" and "possible," however, are not synonymous with "indicated" and "inferred." "Probable" and "possible" describe estimates of partly sampled deposits—in some definitions. For example, "probable" is used to describe deposits sampled on two or three sides, and "possible" for deposits sampled only on one side; in the Bureau-Survey definitions, both would be described by the term "indicated."

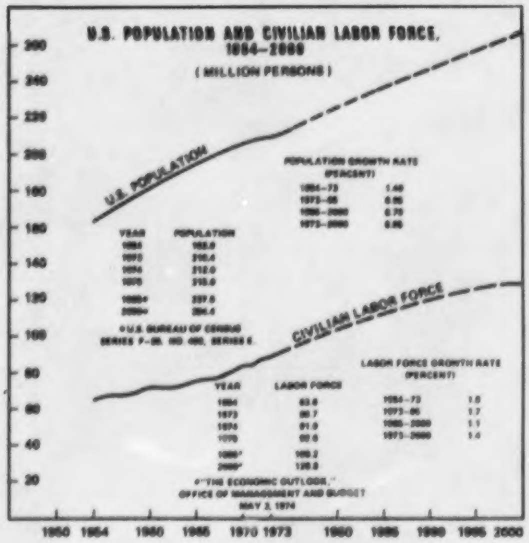

Figure 21.—U.S. population and civilian labor force in million persons, 1954–2000 (*7,20*).

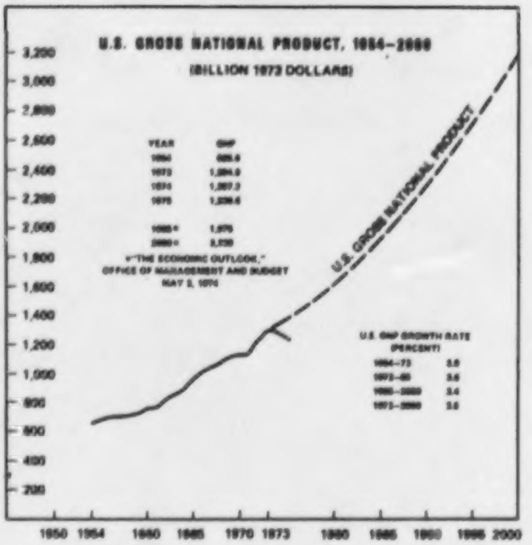

Figure 22.—U.S. gross national product in billion 1973 dollars, 1954–2000 (*20*).

FORECASTING METHODS

Since 1967, the Bureau of Mines has developed and improved a method of forecasting U.S. demand for minerals based on contingency analyses of end uses of each mineral commodity. The current method of forecasting involves three phases of analysis:

1. Quantitative.
2. Qualitative.
3. Probabilistic.

The Data Base

The data base for forecasts and long-term analysis concludes with 1973, the last year for which relatively complete worldwide data were available. The year 1973 is also significant in that both U.S. steel production and energy use reached peaks during that year. The use of many other materials is related closely to steel production. U.S. economic indicators and prices are expressed in terms of constant 1973 dollars. Chapter discussions, however, include the latest data information available at the time of final writing.

The Division of Economic Analysis of the Bureau (DEA) supplied basic data for the following economic indicators:

U.S. Population and Civilian Labor Force, 1954–73 and forecasts to 1985 and 2000, as determined by the Bureau of the Census (7) and the Office of Management and Budget (OMB) (*21*).

U.S. Gross National Product, 1954–73 and forecasts to 1985 and 2000, as reported by OMB (*21*).

U.S. Gross National Product per Capita, 1954–73 and forecasts to 1985 and 2000, as reported by OMB (*21*).

Gross National Product per Civilian Employed, 1954–73 and forecasts to 1985 and 2000, as reported by OMB (*21*).

Federal Reserve Board Index of Industrial Production (1967=100), 1954–73 and forecasts to 1985 and 2000, as reported by OMB (*21*).

New Construction Activity, 1954–73 and forecasts to 1985 and 2000, as reported by OMB (*21*).

Gross Private Domestic Investment, 1954–73 and forecasts to 1985 and 2000, as reported by OMB (*21*).

Personal Consumption Expenditures, 1954–73 and forecasts to 1985 and 2000, as reported by OMB (*21*).

In addition, the Division of Interfuel Studies of the Bureau provided data on *Gross Consumption of Energy Fuels by Major Source*, 1947–73 (9), for coal, natural gas, petroleum, hydropower and geothermal power, nuclear facilities, and total gross energy consumption expressed in British thermal units (Btu) and by weight or volume. Forecasts of five types of energy were tabulated in "*United States Energy Through the Year 2000 (Revised)*" (9) for 1980, 1985, and 2000. The Division also provided data to determine growth rates of energy for 1973 to 1985 and 1973 to 2000 by the following consuming sectors: Household and commercial, industrial, transportation, electrical generation.

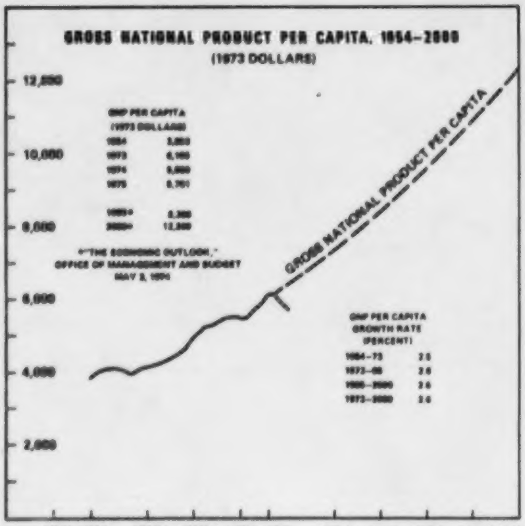

Figure 23.—U.S. gross national product per capita in 1973 dollars, 1954–2000 (*20*).

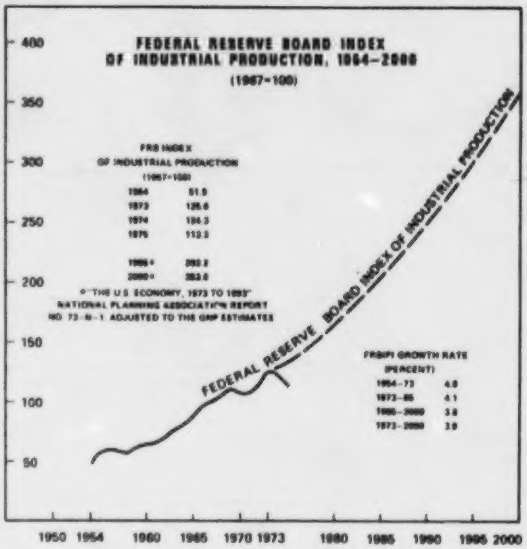

Figure 24.—Federal Reserve Board index of industrial production (1967 = 100), 1954–2000 (*19*).

Figures 21 to 28, inclusive, chart historical trends and forecasts for eight of the forementioned economic indicators.

Quantitative Analysis

Commodity specialists supplied the following data to the Division of Economic Analysis:

End uses of commodities for 1960–73.

U.S. primary production for 1954–73. Primary production is defined as production from domestic mines or wells, and manufactured gases.

U.S. primary demand for 1954–73. Primary demand is defined as demand for minerals produced from domestic or rest-of-world mines or wells and excludes demand for secondary metals (scrap).

DEA then performed a standard regression analysis on each end use of a commodity using the following U.S. economic indicators as explanatory variables:

Gross national product

Federal Reserve Board index of industrial production

Gross private domestic investment

Construction

Population

Gross national product per capita

Projections were then extrapolated for each end use to 1985 and 2000 based on estimated log-log and simple linear regression equations and these projections were used as guides by commodity specialists in making qualitative forecasts.

Primary demand data for 1954–73 were used to calculate the *1973 trend value*. If this trend value deviated substantially (10 percent or more) from the actual 1973 demand figure, the trend value was used to calculate demand growth rates and cumulative demand to 1985 and 2000 rather than the anomalous 1973 figure.

Also time-trend regression analysis was performed on U.S. primary production for 1953–73 to project production to 1985 and 2000.

The foregoing economic indicators and analyses compiled and/or computed by DEA constituted the *quantitative information* supplied to commodity specialists to serve as basic guides in making *qualitative forecasts*.

Qualitative Analysis

The next step in forecasting was the determination of a forecast base for each end use for 2000. In many instances the correlation between the historical growth rate of an end use and that of a particular economic indicator was good, and therefore the commodity specialists used the end-use base projected to 2000 by regression analysis, or the economic indicator growth rate applied to the 1973 demand.

Some commodities are highly interdependent such as iron ore, iron and steel, and the ferroalloy group. Consequently base forecasts for some of the end uses in this group had to be consistent with growth rates forecast for iron and steel demand.

Similarly, in the fertilizer group of minerals,

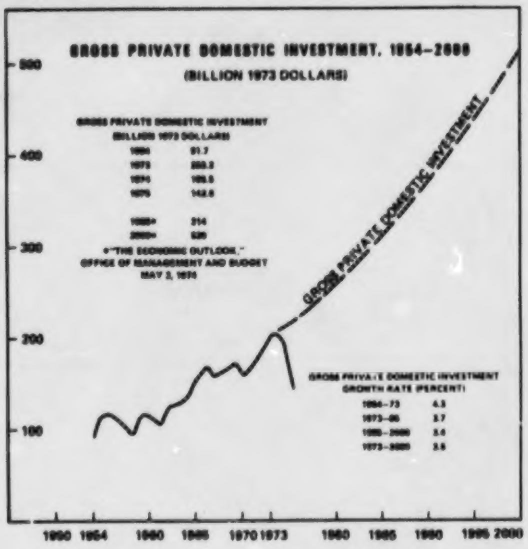

Figure 25.—New construction activity in the United States in billion 1973 dollars, 1954–2000 (*20*).

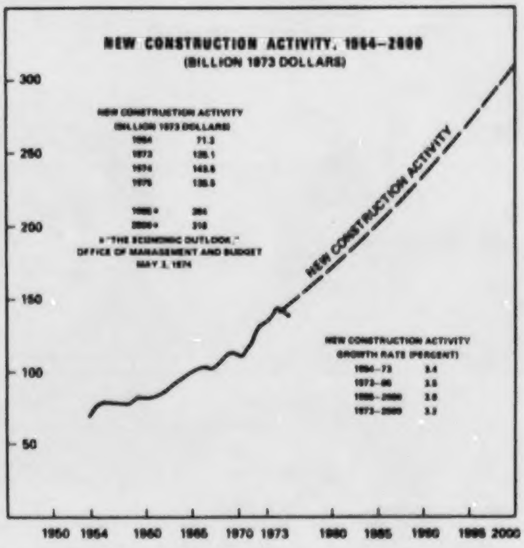

Figure 26.—Gross private domestic investment in billion 1973 dollars, 1954–2000 (*20*).

including phosphate rock, nitrates, potash, and sulfur, base forecasts involved a consideration of a need for the balance of elements in the demand for fertilizers. Contingency estimates for hydrogen consumption in anhydrous ammonia (NH_3) in the Hydrogen chapter were made in a manner consistent with the estimates for ammonia-related end uses in the Nitrogen chapter.

In the energy field, forecast bases for coal, petroleum, natural gas, nuclear fuels, and shale oil had to be consistent with overall energy forecasts compiled by the Division of Interfuel Studies, Bureau of Mines (*9*).

After the forecast bases had been established for each end use, many influencing factors were examined to determine a high and a low range. These mitigating factors included new uses, obsolete uses, technological progress, changes in availability of reserves and resources, substitutes and competitive commodities, environmental restraints or stimuli, price trends, world political developments, sources of materials as byproducts or coproducts, and the recycling of materials.

This system of contingency analysis is the distinctive characteristic of the Bureau of Mines forecasting technique.

Probabilistic Analysis

After establishing a forecast base and a high and low for each end use, the commodity specialist determined a probable forecast for each end use. This appraisal involves weighing those factors and contingencies that are most likely to influence future demand. The forecasts for all end uses of a commodity constitute the forecast for total U.S. primary demand.

Table 1.—Economic indicators used as guides in forecasting

Economic indicator	Growth rates (percent) 1973–85	Growth rates (percent) 1973–2000
Population	0.9	0.8
Civilian labor force	1.7	1.4
Productivity—output per civilian	1.4	1.8
Gross national product	3.6	3.5
FRB index of industrial production (1967 = 100)	4.1	3.9
Gross national product per capita, 1973 dollars	2.6	2.6
New construction activity	3.5	3.2
Energy	3.5	3.3
Energy by consuming sector:		
Household and commercial	.9	.5
Industrial	1.4	1.2
Transportation	1.9	1.7
Electrical generation	6.3	5.5
Gross national product per civilian employed	1.8	2.0
Gross private domestic investment	3.7	3.5
Personal consumption expenditures	3.6	3.5

When secondary metals (old scrap) constitute an appreciable source of supply, as in the case of many metals, the forecasts include the quantity of recovered secondary material estimated to meet a portion of future demand.

Average annual percent growth rates for the forecast periods were calculated with the aid of conventional compound interest tables and "annuity due" tables were used to obtain cumulative totals.

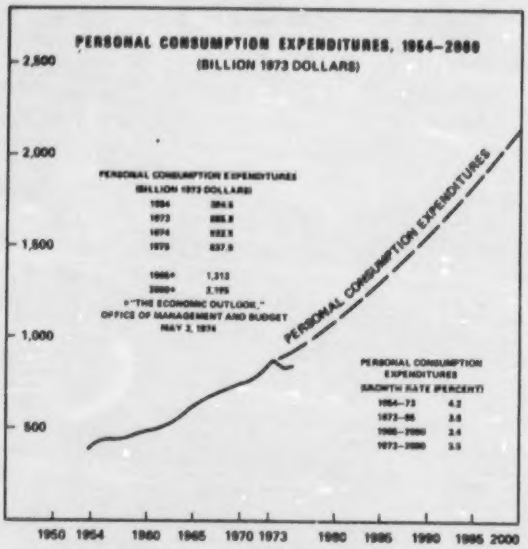

Figure 27.—Personal consumption expenditures in the United States in billion 1973 dollars, 1954–2000 (*20*).

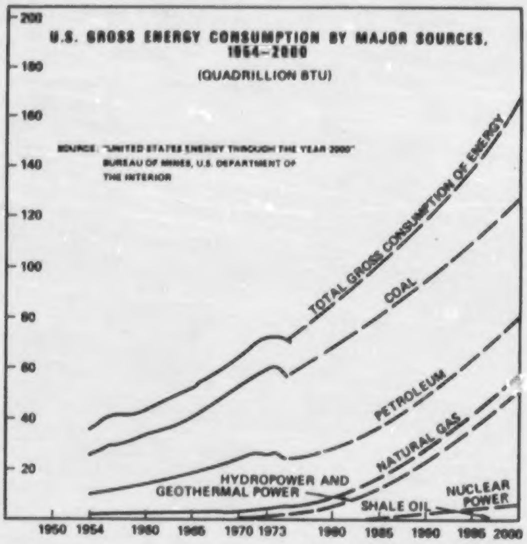

Figure 28.—U.S. gross energy consumption by sources in quadrillion Btu, 1954–2000 (*9*).

Rest-of-the-World Demand

Although detailed end-use data were not available for all commodities and all countries, historical world consumption and production data through 1973 served as one reliable guide in making forecasts for nations other than the United States. In addition, three economic indicators for 1951–2000 (*1*) were available:

World population
World gross domestic product
World gross domestic product per capita

Historical trends and projections to 2000 for these three economic indicators were compiled for the following 10 subdivisions of the world, consisting of 7 groups of developed and developing nations with homogeneous growth patterns and 3 individual nations:

1. Western Europe—OECD countries, plus Greece, Portugal, Spain, and Turkey
2. Japan
3. Other developed lands—Australia, Canada, Israel, New Zealand, and South Africa
4. Union of Soviet Socialist Republics
5. Eastern European countries—centrally controlled economies plus Albania and Yugoslavia
6. Africa—minus South Africa
7. Asia—minus Israel, Japan, People's Republic of China, and related areas.
8. Latin America
9. China—plus Mongolia, North Korea, and North Vietnam
10. United States

Table 2.—U.S. gross energy consumption by major sources, 1973–2000

66	Gross energy consumption (quadrillion Btu)				Growth rates (percent)		
66	1973	1980	1985	2000	1973–1985	1973–2000	1985–2000
Coal	13.29	17.15	21.25	34.75	4.0	3.6	3.3
Petroleum	34.85	41.04	45.63	51.20	2.3	1.4	.8
Natural gas	22.71	20.60	20.10	19.80	−1.0	−.5	−.2
Hydropower and geothermal power	3.00	3.80	3.85	6.07	2.1	2.7	3.1
Nuclear	.89	4.55	11.84	46.08	24.0	15.7	9.5
Shale oil	----	----	.87	1.04	----	----	1.2
Total	74.74	87.14	103.54	163.43	----	----	----

Source: U.S. Bureau of Mines, United States Energy Through the Year 2000 (Revised).

Demand for highly industrialized nations of the world, including some end-use data for major commodities, were helpful in making forecasts for the rest of the world.

U.S. Mine Production Forecasts

Applying the same type of contingency analysis used in demand forecasting, commodity specialists forecast U.S. mine production for 1985 and 2000. Factors weighed in making these forecasts included:

Characteristic and physical environment of resources
Geographic location of resources
Land ownership
Political factors
Environmental factors

TABLE 3.—COMPARISON OF PREVAILNG U.S. PRIMARY MINERAL SUPPLY-DEMAND WITH PROJECTED HISTORICAL TRENDS IN DOMESTIC MINERAL PRODUCTION

		1974		1985			2000		
COMMODITY	UNITS	U.S. PRIMARY* PRODUCTION FROM DOMESTIC SOURCES	U.S. PRIMARY DEMAND	FORECAST U.S. PRIMARY DEMAND	U.S. PRIMARY PRODUCTION IF PAST 20-YEAR TRENDS PREVAIL	U.S. PRIMARY PRODUCTION (ESTIMATED)	FORECAST U.S. PRIMARY DEMAND	U.S. PRIMARY PRODUCTION IF PAST 20-YEAR TRENDS PREVAIL	U.S. PRIMARY PRODUCTION (ESTIMATED)
ALUMINUM	THOUSAND S.T.	458	5,873	11,100	520	700	20,980	590	2,100
ANTIMONY	S.T.	1,319	20,323	30,600	1,480	1,400	49,500	1,320	2,475
ARSENIC	S.T.	(1)	(1)	25,900	1,670	3,200	26,200	1,100	5,100
BARIUM	THOUSAND S.T.	619	930	1,425	515	1,000	1,585	510	1,100
BERYLLIUM	S.T.	(1)	209	430	250	440	1,150	390	800
BISMUTH	THOUSAND LB	(1)	2,365	4,100	1,160	1,200	4,500	1,415	1,600
BORON	THOUSAND S.T.	193	105	185	280	350	340	380	500
BROMINE	MILLION LB	432	363	606	550	700	1,110	760	1,250
CADMIUM	S.T.	2,066	6,187	8,600	2,400	3,000	12,700	2,600	5,000
CESIUM	LB	—	15,100	45,000	—	—	200,000	—	—
CHLORINE	THOUSAND S.T.	10,887	10,944	18,900	15,500	19,000	39,500	22,000	40,000
CHROMIUM	THOUSAND S.T.	—	560	700	—	—	1,100	—	—
COBALT	THOUSAND LB	—	23,183	27,100	—	13,000	43,000	—	40,000
COLUMBIUM	THOUSAND LB	—	7,837	11,000	—	—	22,300	—	—
COPPER	THOUSAND S.T.	1,597	1,953	2,700	2,070	2,500	4,200	2,650	3,800
FLUORINE	THOUSAND S.T.	137	689	1,560	130	100	1,930	130	80
GALLIUM	KG	(1)	7	13,300	3,600	10,000	32,000	5,700	20,000
GERMANIUM	THOUSAND LB	28	44	60	15	40	81	—	54
GOLD	THOUSAND T.OZ	1,127	3,930	7,000	1,120	1,700	15,300	780	2,200
HAFNIUM	S.T.	—	40	50	—	—	80	—	—
INDIUM	THOUSAND T.OZ	(1)	825	980	40	230	1,520	—	300
IODINE	THOUSAND LB	(1)	7,500	10,700	660	3,000	18,000	640	5,000
IRON ORE	MILLION S.T.	58	91	107	60	81	129	70	100
LEAD	THOUSAND S.T.	664	931	1,200	780	720	1,530	1,070	970
LITHIUM	S.T.	(1)	4,530	7,000	5,800	7,500	13,800	8,400	14,800
MAGNESIUM-METAL	THOUSAND S.T.	(1)	123	195	170	250	365	240	300
MAGNESIUM-NONMETALLIC	THOUSAND S.T.	950	1,019	1,500	1,050	1,400	2,550	1,080	2,400
MANGANESE	THOUSAND S.T.	35	1,492	1,680	—	30	2,130	—	—
MERCURY	THOUSAND FL	2	53	53	(2)	25	47	—	25
MOLYBDENUM	THOUSAND LB	112,011	76,400	102,000	158,000	202,600	193,000	214,000	383,400
NICKEL	THOUSAND S.T.	14	219	260	20	100	365	30	270
NITROGEN-COMPOUNDS	THOUSAND S.T.	13,016	12,971	19,000	21,000	16,000	29,000	30,000	25,000
NITROGEN-GAS & LIQUIDS	THOUSAND S.T.	6,875	8,600	12,000	13,000	12,000	18,000	20,000	18,000
PALLADIUM	THOUSAND T.OZ	9	673	975	17	14	1,340	20	22
PLATINUM	THOUSAND T.OZ	4	848	980	1	5	1,225	—	6
RARE EARTHS & YTTRIUM	S.T.	22,482	15,500	22,000	30,000	40,000	34,000	47,000	60,000
RHENIUM	LB	6,700	4,500	7,000	11,200	10,000	9,000	17,700	15,000
RHODIUM	THOUSAND T.OZ	—	51	75	—	—	125	—	—
RUBIDIUM	LB	—	1,210	1,800	—	—	3,000	—	—
SCANDIUM	KG	—	5	8	—	—	17	—	—
SELENIUM	THOUSAND LB	644	1,566	2,100	590	1,200	3,020	440	2,000
SILICON	THOUSAND S.T.	589	686	755	750	740	1,200	1,000	1,000
SILVER	THOUSAND T.OZ	33,800	124,000	160,000	40,000	44,000	230,000	43,000	50,000
STRONTIUM	S.T.	—	19,800	25,200	—	—	34,700	—	—
SULFUR	THOUSAND L.T.	11,419	10,880	14,500	13,400	16,000	23,000	17,100	24,000
TANTALUM	THOUSAND LB	—	1,960	2,300	—	—	4,600	—	—
TELLURIUM	THOUSAND LB	191	324	370	180	330	510	160	490
THALLIUM	LB	(1)	1,850	1,400	480	2,500	1,400	—	3,000
THORIUM	S.T.	(1)	80	90	70	130	260	90	1,000
TIN	L.T.	(1)	45,900	58,000	130	70	64,000	190	70
TITANIUM-METAL	THOUSAND S.T.	—	21	29	—	—	45	—	—
TITANIUM-NONMETALLIC	THOUSAND S.T.	257	525	790	320	363	1,300	370	444
TUNGSTEN	THOUSAND LB	7,381	15,698	26,700	5,800	8,500	49,400	4,100	3,550
VANADIUM	S.T.	5,368	8,453	15,500	7,200	9,100	33,000	8,800	8,700
ZINC	THOUSAND S.T.	500	1,464	2,120	550	600	3,050	570	1,100
ZIRCONIUM-METAL	S.T.	—	3,000	5,000	—	—	12,000	—	—
ZIRCONIUM-NONMETALLIC	THOUSAND S.T.	(1)	68	115	70	100	210	95	200

Technological change
Nature of existing production capability
Byproduct and coproduct production
Health and safety regulations and considerations
Conservation
Availability of manpower
Energy and water requirements

In addition, DEA supplied projections made by regression analysis of the 20-year production trends for each commodity.

MINERAL TRENDS AND FORECASTS

These data presented in summary table form result from a continuous study conducted by the Bureau of Mines for the purpose of identifying

TABLE 3.—COMPARISON OF PREVAILING U.S. PRIMARY MINERAL SUPPLY-DEMAND WITH PROJECTED HISTORICAL TRENDS IN DOMESTIC MINERAL PRODUCTION (CONTINUED)

COMMODITY	UNITS	1974		1985			2000		
		U.S. PRIMARY* PRODUCTION FROM DOMESTIC SOURCES	U.S. PRIMARY DEMAND	FORECAST U.S. PRIMARY DEMAND	U.S. PRIMARY PRODUCTION IF PAST 20-YEAR TRENDS PREVAIL	U.S. PRIMARY PRODUCTION (ESTIMATED)	FORECAST U.S. PRIMARY DEMAND	U.S. PRIMARY PRODUCTION IF PAST 20-YEAR TRENDS PREVAIL	U.S. PRIMARY PRODUCTION (ESTIMATED)
ASBESTOS	THOUSAND S.T.	113	846	895	220	160	1,114	300	200
CLAYS	MILLION S.T.	61	59	101	71	100	181	84	190
CORUNDUM	S.T.	—	1,000	840	—	—	1,000	—	—
DIAMOND-INDUSTRIAL	THOUSAND KT	19,000	25,100	37,000	28,000	30,000	69,500	43,000	50,000
DIATOMITE	THOUSAND S.T.	664	478	815	800	1,000	1,785	1,000	2,000
FELDSPAR	THOUSAND S.T.	854	833	1,150	950	1,150	2,000	1,150	2,000
GARNET	THOUSAND S.T.	25	20	26	32	31	39	43	53
GRAPHITE	THOUSAND S.T.	(1)	97	96	—	—	129	—	—
GYPSUM	THOUSAND S.T.	11,999	18,693	26,000	12,200	15,000	34,800	13,600	20,000
KYANITE	THOUSAND S.T.	(1)	(1)	250	230	320	500	330	650
LIME	THOUSAND S.T.	21,645	22,029	29,300	30,000	29,000	43,300	40,000	43,000
MICA-SCRAP & FLAKE	THOUSAND S.T.	137	124	185	180	190	215	230	234
MICA-SHEET	THOUSAND LB	—	7,160	4,000	—	—	1,410	—	—
PERLITE	THOUSAND S.T.	555	535	825	700	900	1,500	900	1,600
PHOSPHATE ROCK	THOUSAND S.T.	45,686	34,720	45,000	65,800	80,000	69,000	92,600	85,000
POTASH	THOUSAND S.T.	2,552	6,084	9,000	3,300	2,000	12,000	3,700	1,000
PUMICE	THOUSAND S.T.	3,937	4,227	6,100	5,400	6,500	10,160	7,200	10,600
QUARTZ CRYSTAL	THOUSAND LB	—	285	400	—	—	620	—	—
SALT	THOUSAND S.T.	46,423	49,154	75,000	65,000	77,800	136,400	87,000	129,300
SAND & GRAVEL	MILLION S.T.	978	978	1,390	1,240	1,390	2,090	1,550	2,090
SODA ASH	THOUSAND S.T.	7,561	7,058	10,180	9,070	11,000	15,630	11,100	17,000
STONE-CRUSHED	MILLION S.T.	1,042	1,041	1,550	1,300	1,550	2,500	1,800	2,500
STONE-DIMENSION	THOUSAND S.T.	1,915	1,915	1,700	1,000	1,500	1,700	120	1,500
TALC	THOUSAND S.T.	1,268	1,064	1,500	1,500	1,700	2,150	1,900	2,400
VERMICULITE	THOUSAND S.T.	341	324	500	440	525	900	570	950
ANTHRACITE	MILLION S.T.	7	5	5	—	6	5	—	6
BITUMINOUS COAL & LIGNITE	MILLION S.T.	603	553	918	700	993	1,555	850	1,655
NATURAL GAS[3]	BILLION C.F.	21,601	21,223	19,510	32,100	18,210	19,030	43,600	16,530
PEAT	THOUSAND S.T.	731	1,033	1,400	920	932	2,200	1,200	1,506
PETROLEUM[4]	MILLION BBL	3,819	6,078	8,265	5,100	5,307	9,274	6,300	4,964
SHALE OIL	MILLION BBL	—	—	110	—	110	730	—	730
URANIUM (NUCLEAR)	S.T.	9,776	8,000	41,000	12,700	36,000	69,500	14,400	60,000
ARGON	THOUSAND S.T.	241	241	360	330	360	660	500	660
HELIUM	MILLION C.F.	699	[5]570	NA	NA	NA	NA	NA	NA
HYDROGEN	BILLION C.F.	2,570	2,570	4,345	4,400	4,345	14,450	6,600	14,450
OXYGEN	THOUSAND S.T.	16,127	16,127	32,000	26,100	32,000	62,000	38,600	62,000

NA NOT AVAILABLE. *PRIMARY PRODUCTION MEANS PRODUCTION FROM DOMESTIC MINES OR WELLS, AND MANUFACTURED GASES.

[1] CERTAIN DATA ARE WITHHELD BECAUSE OF INDIVIDUAL COMPANY CONFIDENTIALITY.

[2] LESS THAN ONE UNIT.

[3] GAS CONTAINING LITTLE OR NO HYDROCARBONS COMMERCIALLY RECOVERABLE AS LIQUID PRODUCT.

[4] INCLUDES NATURAL GAS LIQUIDS.

[5] REVISED.

how the national interest might be affected by apparent changes in worldwide mineral supply-demand relationships. The data are directed to the individual mineral-forming elements, common fossil fuels, and certain gases and mineral forms that have, or might have, some commercial significance.

Although the data are revised frequently to reflect any significant changes in supply-demand patterns or end-use applications, a comprehensive updating is performed annually as current critical data relating to world production and consumption become available. Accordingly the tables have been revised to reflect relationships that became apparent at the close of 1974, the latest year for which relatively complete reconciled worldwide data are in hand. Similarly all analyses of probable future patterns have been re-estimated in light of current information and the emerging factors that would seem to influence future relationships.

The minor discrepencies that exist between the forecasts in the commodity chapters which were based on 1973 data and conditions, and the following tables based on 1974 data, illustrate the necessity of revising these trends and forecasts on an annual basis.

Reserves are particulary sensitive to changes in price, new mineral discoveries, and technological progress. Similarly, supply-demand estimates are subject to revision annually because of new uses, substitutions, environmental developments, and the substantial changes and expansions in the industrial world as indicated in the preceding two-century "Time Capsule."

Primary production means production from

TABLE 4.—AVERAGE ANNUAL GROWTH IN U.S. PRIMARY MINERAL DEMAND DURING 1950–1960, 1960–1970, 1970–1974, WITH GROWTH FORECAST FOR 1974–1985 and 1974–2000

(PERCENT)

COMMODITY	1950–1960	1960–1970	1970–1974	1974–1985	1974–2000
ALUMINUM	5.7	9.6	9.6	5.9	5.0
ANTIMONY	−2.7	2.1	9.0	3.8	3.5
ARSENIC	−2.7	0.9	6.0	0.1	0.1
BARIUM	4.2	1.7	4.3	4.0	2.1
BERYLLIUM	12.5	−0.3	−10.2	6.8	6.8
BISMUTH	−0.2	2.1	1.4	5.1	2.5
BORON	4.0	4.6	4.5	5.3	4.6
BROMINE	8.4	7.4	1.5	4.8	4.6
CADMIUM	0.3	−0.7	8.1	3.1	2.8
CESIUM	—	7.6	28.0	10.5	10.4
CHLORINE	8.5	8.0	2.9	5.1	5.1
CHROMIUM	4.5	2.7	3.3	2.1	2.8
COBALT	7.9	4.2	9.4	1.4	3.0
COLUMBIUM	37.0	7.5	11.4	3.1	4.1
COPPER	−1.4	3.6	5.6	3.0	3.0
FLUORINE	4.5	7.6	3.4	7.7	4.0
GALLIUM	32.0	4.2	+50.0	6.1	6.1
GERMANIUM	—	−2.7	2.4	2.9	2.4
GOLD	1.0	7.1	−11.3	5.4	5.4
HAFNIUM	—	3.8	3.3	2.1	2.7
INDIUM	9.0	6.3	10.7	1.6	2.4
IODINE	3.4	10.0	4.5	4.2	3.4
IRON ORE	0.4	2.6	2.0	1.5	1.4
LEAD	−2.6	4.4	2.9	2.3	1.9
LITHIUM	18.0	7.6	15.0	4.6	4.6
MAGNESIUM-METAL	11.0	6.5	6.4	4.3	4.3
MAGNESIUM-NONMETALLIC	2.9	0.8	−0.9	3.6	3.6
MANGANESE	0.4	2.1	3.0	1.1	1.6
MERCURY	−0.2	1.6	−0.3	−0.1	−0.5
MOLYBDENUM	6.3	2.8	11.7	2.7	3.6
NICKEL	2.0	2.5	7.7	1.6	2.6
NITROGEN-COMPOUNDS	15.6	7.7	4.3	3.5	3.1
NITROGEN-GAS & LIQUIDS	37.0	23.0	11.8	3.1	2.9
PALLADIUM	11.4	3.5	6.2	3.4	2.7
PLATINUM	0.5	3.5	21.0	1.3	1.4
RARE EARTHS & YTTRIUM	10.9	17.8	7.5	3.2	3.1
RHENIUM	—	20.0	−3.2	4.1	2.7
RHODIUM	5.5	4.2	9.1	3.6	3.5
RUBIDIUM	—	−0.8	16.8	3.7	3.6
SCANDIUM	—	—	−34.0	4.4	4.8
SELENIUM	−3.7	3.8	9.1	2.7	2.6
SILICON	−0.8	7.6	6.6	0.9	2.7
SILVER	0.9	−7.3	13.9	2.4	2.4
STRONTIUM	−1.9	19.3	0.9	2.2	2.2
SULFUR	1.6	4.5	4.2	2.6	2.9
TANTALUM	13.0	8.2	16.7	6.1	3.3
TELLURIUM	8.1	2.7	4.6	1.2	1.8
THALLIUM	−4.8	8.1	−35.0	−2.6	−1.1
THORIUM	16.9	0.2	19.0	1.1	4.6
TIN	−2.2	−1.1	−4.1	2.1	1.3
TITANIUM-METAL	23.0	11.6	−3.4	3.0	3.0
TITANIUM-NONMETALLIC	4.3	3.5	3.0	3.8	3.8
TUNGSTEN	5.6	3.6	0.2	4.9	4.5
VANADIUM	7.3	12.2	4.6	5.7	5.4
ZINC	−1.8	3.1	2.7	3.4	2.9
ZIRCONIUM-METAL	17.5	—	13.6	4.8	5.5
ZIRCONIUM-NONMETALLIC	14.5	7.2	−0.5	4.8	4.4
ASBESTOS	−0.3	0.3	3.6	0.5	1.1
CLAYS	2.3	0.8	2.7	5.1	4.4
CORUNDUM	−2.8	−2.9	−18.9	−1.6	—
DIAMOND-INDUSTRIAL	9.6	−5.8	10.2	3.6	4.0
DIATOMITE	5.9	1.4	1.9	4.9	5.4
FELDSPAR	1.4	2.1	6.5	3.0	3.4
GARNET	0.2	5.8	5.6	2.6	2.7
GRAPHITE	0.2	0.4	15.3	0.1	1.1
GYPSUM	2.4	0.2	6.9	3.0	2.4
KYANITE	5.1	6.2	−4.2	8.0	6.1
LIME	5.7	4.4	2.6	2.6	2.6
MICA-SCRAP & FLAKE	2.9	1.9	1.3	3.7	2.2
MICA-SHEET	−4.9	−1.7	2.4	−5.4	−6.0
PERLITE	11.5	4.0	5.0	4.0	4.0
PHOSPHATE ROCK	4.5	6.2	6.3	2.4	2.7
POTASH	5.2	7.3	6.5	3.6	2.6
PUMICE	11.9	4.4	5.6	3.4	3.4
QUARTZ CRYSTAL	7.3	−3.4	14.6	3.1	3.0
SALT	4.7	6.4	0.3	3.9	4.0
SAND & GRAVEL	6.8	2.9	0.9	3.3	3.0
SODA ASH	2.6	2.4	1.1	3.4	3.2
STONE-CRUSHED	18.6	3.9	4.6	3.7	3.4
STONE-DIMENSION	2.0	−2.6	2.4	−1.1	−0.5
TALC	1.4	2.9	2.9	3.2	2.7
VERMICULITE	−0.5	1.2	10.0	4.0	4.0
ANTHRACITE	−8.3	−8.4	−11.3	—	—
BITUMINOUS COAL & LIGNITE	−1.9	3.2	1.7	4.7	4.1
NATURAL GAS	7.6	5.7	0.7	−0.8	−0.4
PEAT	11.2	0.9	6.6	2.8	2.9
PETROLEUM	4.2	4.1	3.2	2.8	1.6
SHALE OIL	—	—	—	—	—
URANIUM	8.8	40.0	18.9	16.0	8.7
ARGON	26.0	17.8	14.2	2.6	4.0
HELIUM	19.2	2.2	[1]1.3	NA	NA
HYDROGEN	14.0	13.8	4.3	4.9	6.8
OXYGEN	14.2	12.9	4.9	6.5	5.3

NA NOT AVAILABLE.

[1] REVISED.

domestic mines or wells, and manufactured gases. Demand for primary minerals means demand for minerals produced from domestic or rest-of-world mines or wells and excludes demand for secondary metals (old scrap).

The tables included in trends and forecasts are as follows:

Table 3.—Comparison of prevailing U.S. primary mineral supply-demand with projected historical trends in domestic mineral production.
Table 4.—Average annual growth in U.S. primary mineral demand during 1950–1960, 1960–1970, 1970–1974, with growth forecast for 1974–1985, and 1974–2000.
Table 5.—U.S. percapita primary mineral demand in 1950, 1960, 1970, and 1974, with forecast demand in 1985 and 2000.
Table 6.—U.S. total mineral demand in 1974 by end use.
Table 7.—World primary mineral demand in 1974, with projected demand in 1985, and cumulative demand 1974–1985.
Table 8.—World primary mineral demand in 1974, with projected demand in 200, and cumulative demand in 1974–2000.
Table 9.—U.S. secondary metal (old scrap) demand in 1950, 1960, 1970, and 1974.
Table 10.—U.S. forecasted secondary metal (old scrap) demand in 1985 and 2000.
Table 11.—World mineral reserves, 1974.
Table 12.—Comparison of world cumulative primary mineral demand forecasts, 1974–2000, with world mineral reserves, 1974.
Table 13.—Comparison of world cumulative primary mineral demand forecasts, 1974–2000, with world identified mineral resources.

TABLE 6.—U.S. PER CAPITA PRIMARY MINERAL DEMAND IN 1950, 1960, 1970, AND 1974, WITH FORECAST DEMAND IN 1985 AND 2000

COMMODITY	UNITS	PER CAPITA PRIMARY DEMAND[1]					
		1950	1960	1970	1974	1985	2000
ALUMINUM	POUNDS	12.0	17.5	36.6	55.5	94.1	168.6
ANTIMONY	POUNDS	.2	.1	.1	.2	.3	.4
ARSENIC	POUNDS	.3	.2	.2	.2	.2	.2
BARIUM	POUNDS	5.6	7.4	7.7	8.6	12.1	12.0
BERYLLIUM	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
BISMUTH	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
BORON	POUNDS	.5	.6	.8	1.0	1.6	2.6
BROMINE	POUNDS	.5	.9	1.7	1.7	2.6	4.2
CADMIUM	POUNDS	.1	.1	(2)	.1	.1	.1
CESIUM	POUNDS	—	(2)	(2)	(2)	(2)	(2)
CHLORINE	POUNDS	36.3	50.2	95.2	103.2	190.2	389.2
CHROMIUM	POUNDS	3.0	3.9	4.5	5.3	5.9	8.3
COBALT	POUNDS	(2)	.1	.1	.1	.1	.2
COLUMBIUM	POUNDS	(2)	(2)	(2)	(2)	(2)	.1
COPPER	POUNDS	16.7	12.2	15.3	18.4	22.9	31.9
FLUORINE	POUNDS	2.5	3.2	6.0	6.6	13.2	14.6
GALLIUM	GRAMS	(2)	(2)	(2)	(2)	(2)	(2)
GERMANIUM	POUNDS	NA	(2)	(2)	(2)	(2)	(2)
GOLD	TROY OUNCES	(2)	(2)	(2)	(2)	(2)	.1
HAFNIUM	POUNDS	—	(2)	(2)	(2)	(2)	(2)
INDIUM	TROY OUNCES	(2)	(2)	(2)	(2)	(2)	(2)
IODINE	POUNDS	(2)	(2)	(2)	(2)	(2)	.1
IRON ORE	POUNDS	814.2	718.4	820.3	858.5	906.8	977.3
LEAD	POUNDS	9.2	8.0	8.1	8.8	10.2	11.6
LITHIUM	POUNDS	(2)	(2)	(2)	(2)	.1	.1
MAGNESIUM-METAL	POUNDS	.2	.6	.9	1.2	1.7	2.8
MAGNESIUM-NONMETALLIC	POUNDS	9.6	10.6	10.3	9.8	12.7	18.3
MANGANESE	POUNDS	13.6	11.9	12.9	14.1	14.2	18.1
MERCURY	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
MOLYBDENUM	POUNDS	.1	.2	.2	.4	.4	.7
NICKEL	POUNDS	1.3	1.3	1.5	2.1	2.2	2.9
NITROGEN-COMPOUNDS	POUNDS	15.2	54.4	101.2	122.6	181.0	219.7
NITROGEN-GAS & LIQUIDS	POUNDS	.4	7.4	51.8	84.9	101.7	138.4
PALLADIUM	TROY OUNCES	(2)	(2)	(2)	(2)	(2)	(2)
PLATINUM	TROY OUNCES	(2)	(2)	(2)	(2)	(2)	(2)
RARE EARTHS & YTTRIUM	POUNDS	(2)	(2)	.1	.1	.2	.3
RHENIUM	POUNDS	—	(2)	(2)	(2)	(2)	(2)
RHODIUM	TROY OUNCES	(2)	(2)	(2)	(2)	(2)	(2)
RUBIDIUM	POUNDS	—	(2)	(2)	(2)	(2)	(2)
SCANDIUM	POUNDS	—	—	(2)	(2)	(2)	(2)
SELENIUM	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
SILICON	POUNDS	3.6	2.8	5.2	6.5	6.4	9.1
SILVER	TROY OUNCES	.9	.8	.4	.6	.7	.9
STRONTIUM	POUNDS	.1	(2)	.2	.2	.2	.3
SULFUR	POUNDS	73.5	72.7	99.9	115.0	137.8	186.2
TANTALUM	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
TELLURIUM	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
THALLIUM	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
THORIUM	POUNDS	(2)	(2)	(2)	(2)	(2)	
TIN	POUNDS	1.1	.7	.6	.5	.5	.5
TITANIUM-METAL	POUNDS	(2)	.1	.2	.2	.2	.3
TITANIUM-NONMETALLIC	POUNDS	2.8	3.6	4.5	5.0	6.7	10.5
TUNGSTEN	POUNDS	(2)	.1	.1	.1	.1	.2
VANADIUM	POUNDS	(2)	(2)	.1	.1	.1	.3
ZINC	POUNDS	15.1	10.6	12.7	13.9	18.0	23.1
ZIRCONIUM-METAL	POUNDS	(2)	(2)	(2)	(2)	(2)	.1
ZIRCONIUM-NONMETALLIC	POUNDS	.1	.4	.7	.8	1.0	1.8
ASBESTOS	POUNDS	9.5	7.8	7.2	8.0	7.6	8.4
CLAYS	POUNDS	512.1	542.3	517.6	553.6	868.9	1,371.2
CORUNDUM	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
DIAMOND-INDUSTRIAL	KARATS	(2)	(2)	(2)	.1	.2	.3
DIATOMITE	POUNDS	2.9	4.3	4.3	4.5	6.9	13.6
EMERY	POUNDS	(2)	(2)	(2)	—	—	—
FELDSPAR	POUNDS	6.0	5.8	6.3	7.9	9.7	15.2
GARNET	POUNDS	.1	.1	.1	.2	.2	.3
GRAPHITE	POUNDS	.6	.5	.3	.9	.6	1.0
GYPSUM	POUNDS	145.5	165.0	140.0	178.3	220.3	363.6
KYANITE	POUNDS	.5	.8	1.2	1.0	2.1	3.8
LIME	POUNDS	99.0	143.2	194.2	207.8	248.3	328.0
MICA-SCRAP & FLAKE	POUNDS	1.0	1.1	1.2	1.2	1.6	1.6
MICA-SHEET	POUNDS	.1	(2)	(2)	(2)	(2)	(2)
PERLITE	POUNDS	1.3	3.3	4.3	6.0	7.0	11.4
PHOSPHATE ROCK	POUNDS	126.2	165.3	265.1	327.5	361.4	522.7
POTASH	POUNDS	18.5	25.9	48.1	57.4	78.3	90.9
PUMICE	POUNDS	9.7	25.1	34.1	39.9	51.7	77.0
QUARTZ CRYSTAL	POUNDS	(2)	(2)	(2)	(2)	(2)	(2)
SALT	POUNDS	126.0	269.0	474.4	463.7	635.6	1,033.3
SAND & GRAVEL	TONS	2.4	3.9	4.6	4.8	5.9	7.9
SODA ASH	POUNDS	52.9	37.7	64.3	66.6	86.3	118.4
STONE-CRUSHED	TONS	.5	2.4	3.2	5.8	6.8	9.5
STONE-DIMENSION	POUNDS	24.4	25.0	17.0	18.1	14.4	12.9
TALC	POUNDS	8.1	7.9	9.2	10.0	12.7	16.3
VERMICULITE	POUNDS	2.7	2.2	2.1	3.1	4.2	6.6
ANTHRACITE	POUNDS	525.3	190.2	79.1	47.2	42.4	37.8
BITUMINOUS COAL & LIGNITE	TONS	3.0	2.1	2.5	2.6	3.9	5.9
NATURAL GAS	THOUSAND C.F.	38.7	67.9	104.3	100.1	82.8	72.0
PEAT	POUNDS	3.3	8.1	7.8	9.7	11.9	16.7
PETROLEUM[3]	BBL	15.6	19.8	26.2	26.7	35.1	35.1
SHALE OIL	BBL	—	—	—	—	.5	2.8
URANIUM	POUNDS	(2)	(2)	.1	.1	.3	.5
ARGON	POUNDS	(2)	.3	1.5	2.3	3.1	5.8
HELIUM	C.F.	.5	2.6	2.9	2.7	NA	NA
HYDROGEN	THOUSAND C.F.	1.1	3.6	11.4	12.1	18.4	34.7
OXYGEN	POUNDS	13.5	43.0	127.8	150.9	271.2	469.7

NA NOT AVAILABLE.

[1] POPULATION, MILLIONS: 1974, 211.9; 1985, 235.7; 2000, 264.4.

[2] LESS THAN ONE-TENTH UNIT.

[3] INCLUDES NATURAL GAS LIQUIDS.

TABLE 6.—U.S. TOTAL MINERAL DEMAND IN 1974, BY END USE

COMMODITY	UNITS	20 FOOD PRODUCTS	26 PAPER PRODUCTS	28 CHEMICALS	30 RUBBER PRODUCTS	32 NON-METALLIC PRODUCTS	33 PRIMARY METALS INDUSTRIES
ALUMINUM	THOUSAND S.T.	—	—	377	—	386	—
ANTIMONY	S.T.	—	—	14,125	3,880	2,420	—
ARSENIC	S.T.	—	—	(1)	—	(1)	—
BARIUM	THOUSAND S.T.	—	—	86	—	—	—
BERYLLIUM	S.T.	—	—	—	—	—	—
BISMUTH	THOUSAND LB	—	—	1,006	—	—	584
BORON	THOUSAND S.T.	—	—	28	—	46	—
BROMINE	MILLION LB	—	—	92	—	—	—
CADMIUM	S.T.	—	—	2,100	—	—	—
CESIUM	LB	—	—	410	—	—	—
CHLORINE	THOUSAND S.T.	—	1,870	6,880	—	—	—
CHROMIUM	THOUSAND S.T.	—	—	61	—	86	—
COBALT	THOUSAND LB	—	—	4,717	—	2,207	—
COLUMBIUM	THOUSAND LB	—	—	—	—	—	—
COPPER	THOUSAND S.T.	—	—	—	-	—	—
FLUORINE	THOUSAND S.T.	—	—	294	—	9	464
GALLIUM	KG	—	—	—	—	—	—
GERMANIUM	THOUSAND LB	—	—	—	—	—	—
GOLD	THOUSAND T.OZ	—	—	—	—	—	—
HAFNIUM	S.T.	—	—	—	—	2	—
INDIUM	THOUSAND T.OZ	—	—	—	—	—	250
IODINE	THOUSAND LB	1,200	—	5,600	—	—	—
IRON	MILLION S.T.	—	—	—	—	—	—
LEAD	THOUSAND S.T.	—	—	116	—	—	—
LITHIUM	S.T.	—	—	—	—	1,300	1,700
MAGNESIUM-METAL	THOUSAND S.T.	—	—	9	—	—	19
MAGNESIUM-NONMETALLIC	THOUSAND S.T.	—	—	100	—	919	—
MANGANESE	THOUSAND S.T.	—	—	66	—	—	—
MERCURY	THOUSAND FL	—	—	24	—	—	—
MOLYBDENUM	THOUSAND LB	—	—	7,346	—	—	—
NICKEL	THOUSAND S.T.	—	—	43	—	—	—
NITROGEN-COMPOUNDS	THOUSAND S.T.	200	70	10,830	80	—	—
NITROGEN-GAS & LIQUID	THOUSAND S.T.	1,460	—	4,800	—	—	880
PALLADIUM	THOUSAND T.OZ	—	—	163	—	—	—
PLATINUM	THOUSAND T.OZ	—	—	216	—	74	—
RARE EARTHS & YTTRIUM	S.T.	—	—	—	—	2,000	5,300
RHENIUM	LB	—	—	—	—	—	—
RHODIUM	THOUSAND T.OZ	—	—	24	—	7	—
RUBIDIUM	LB	—	—	100	—	—	—
SCANDIUM	KG	—	—	—	—	—	—
SELENIUM	THOUSAND LB	—	—	206	—	340	—
SILICON	THOUSAND S.T.	—	—	34	—	—	—
SILVER	MILLION T.OZ	—	—	—	—	—	—
STRONTIUM	S.T.	—	—	4,580	—	600	800
SULFUR	THOUSAND L.T.	—	390	7,300	—	—	670
TANTALUM	THOUSAND LB	—	—	—	—	—	—
TELLURIUM	THOUSAND LB	—	—	19	—	—	280
THALLIUM	LB	—	—	300	—	—	—
THORIUM	S.T.	—	—	—	—	6	—
TIN	L.T.	—	—	4,900	—	—	—
TITANIUM-METAL	THOUSAND S.T.	—	—	—	—	—	—
TITANIUM-NONMETALLIC	THOUSAND S.T.	—	101	367	15	14	—
TUNGSTEN	THOUSAND LB	—	—	486	—	—	—
VANADIUM	S.T.	—	—	991	—	—	—
ZINC	THOUSAND S.T.	—	—	95	120	—	—
ZIRCONIUM-METAL	S.T.	—	—	—	—	—	—
ZIRCONIUM-NONMETALLIC	THOUSAND S.T.	—	—	1	—	27	40
ASBESTOS	THOUSAND S.T.	—	63	—	—	—	—
CLAYS	THOUSAND S.T.	—	2,342	—	—	6,593	870
CORUNDUM	S.T.	—	—	—	—	480	—
DIAMOND-INDUSTRIAL	THOUSAND KT	—	—	—	—	7,300	1,800
DIATOMITE	THOUSAND S.T.	—	—	110	—	287	—
FELDSPAR	THOUSAND S.T.	—	—	—	—	707	—
GARNET	S.T.	—	—	—	—	19,000	—
GRAPHITE	THOUSAND S.T.	—	—	—	—	25	24
GYPSUM	THOUSAND S.T.	—	—	1,871	—	326	—
KYANITE	THOUSAND S.T.	—	—	—	—	(1)	(1)
LIME	THOUSAND S.T.	—	—	109	—	1,277	19,160
MICA-SCRAP & FLAKE	THOUSAND S.T.	—	—	34	7	41	—
MICA-SHEET	THOUSAND LB	—	—	—	—	—	—
PERLITE	THOUSAND S.T.	—	—	32	—	91	—
PHOSPHATE ROCK	THOUSAND S.T.	2,779	—	30,563	—	—	—
POTASH	THOUSAND S.T.	—	—	8,096	—	—	—
PUMICE	THOUSAND S.T.	—	—	—	—	26	—
QUARTZ CRYSTAL	THOUSAND LB	—	—	—	—	—	—
SALT	THOUSAND S.T.	3,418	4,009	27,894	—	3,089	1,888
SAND & GRAVEL	MILLION S.T.	—	—	—	—	10	7
SODA ASH	THOUSAND S.T.	—	475	2,200	—	2,900	—
STONE-CRUSHED	MILLION S.T.	—	—	38	—	—	32
STONE-DIMENSION	THOUSAND S.T.	—	—	—	—	821	—
TALC	THOUSAND S.T.	—	89	240	25	283	—
VERMICULITE	THOUSAND S.T.	—	—	38	—	—	—
ANTHRACITE	THOUSAND S.T.	—	—	386	—	122	870
BITUMINOUS COAL & LIGNITE	THOUSAND S.T.	5,160	9,430	13,080	—	8,100	96,802
NATURAL GAS	BILLION C.F.	443	460	1,480	—	700	1,080
PEAT	THOUSAND S.T.	—	—	1,018	—	—	—
PETROLEUM[2]	MILLION BBL	25	36	480	—	19	68
SHALE OIL	THOUSAND BBL	—	—	—	—	—	—
URANIUM[3]	S.T.	—	—	—	—	—	—
ARGON	THOUSAND S.T.	—	—	15	—	—	20
HELIUM[4]	MILLION C.F.	—	—	—	—	—	60
HYDROGEN	BILLION C.F.	—	—	1,425	—	—	18
OXYGEN	THOUSAND S.T.	—	—	1,850	—	—	12,100

[1] CERTAIN DATA ARE WITHHELD BECAUSE OF INDIVIDUAL COMPANY CONFIDENTIALITY.

[2] INCLUDES NATURAL GAS LIQUIDS.

[3] NUCLEAR AND NONFUEL USES (DEPLETED URANIUM).

[4] HELIUM DEMAND AND END-USE NUMBERS REVISED.

TABLE 6.—U.S. TOTAL MINERAL DEMAND IN 1974, BY END USE (CONTINUED)

34 FABRICATED METAL PRODUCTS	35 MACHINERY	36 ELECTRICAL	38 INSTRUMENTS	39 JEWELRY & ARTS	49 ELECTRIC, GAS & SANITARY SERVICES	28, 32, 33, 34 CONSTRUCTION	13, 29, 46, 49 OIL & GAS INDUSTRIES	29, 32, 36, 37 TRANSPORTATION	65, 70, 88 HOUSEHOLD & COMMERCIAL	OTHER	TOTAL
996	482	1,287	—	—	—	1,236	—	1,067	—	322	6,322
—	2,046	—	—	—	—	—	—	19,120	—	1,720	43,323
—	—	—	—	—	—	—	—	—	—	(1)	(1)
—	—	—	—	—	—	—	606	—	—	40	931
—	—	86	—	—	56	—	—	46	—	23	209
—	772	—	—	—	—	—	—	—	—	10	2,374
10	—	—	—	—	—	—	—	—	—	24	106
—	—	—	—	—	—	—	240	—	—	31	383
1,800	—	600	—	—	—	—	—	1,100	—	460	6,060
—	—	980	—	—	—	—	—	—	—	13,710	15,100
—	—	—	—	—	690	—	—	—	—	1,734	10,944
57	90	—	—	—	—	140	—	103	—	86	605
—	8,012	5,570	—	—	—	—	—	5,236	—	612	23,463
—	1,176	—	—	—	—	3,135	1,567	1,567	—	392	7,837
—	340	1,250	—	—	—	425	—	257	—	164	2,436
—	—	—	—	—	—	—	—	—	—	2	699
—	—	—	6,700	—	—	—	—	—	—	300	7,000
—	—	22	21	—	—	—	—	—	—	1	44
—	—	1,714	501	2,365	—	—	—	—	—	—	4,580
—	—	2	29	—	—	—	—	—	—	1	32
—	—	180	300	—	—	—	—	—	—	125	635
—	—	—	300	—	—	—	—	—	—	400	7,800
9	29	8	—	—	—	36	8	36	—	8	136
87	—	133	—	—	—	79	250	786	—	83	1,532
—	300	—	—	—	—	—	900	—	—	690	4,630
—	44	—	—	—	—	—	—	44	—	13	129
—	—	—	—	—	—	—	—	—	—	—	1,019
79	346	86	—	—	—	317	69	315	—	315	1,462
—	—	19	9	—	—	—	—	—	—	8	60
—	17,605	2,754	—	—	—	—	19,613	19,862	—	3,788	71,165
26	23	56	—	—	—	29	26	60	—	21	264
—	—	—	—	—	—	—	—	—	—	1,880	12,880
—	—	600	—	—	—	—	—	—	—	1,125	8,575
—	—	380	124	22	—	—	15	150	—	22	686
—	—	99	26	23	—	—	139	380	—	17	944
—	—	—	—	—	—	—	6,800	—	—	800	15,500
—	—	—	300	—	—	—	3,600	—	—	600	4,500
—	—	16	—	10	—	—	—	—	—	5	62
—	—	210	—	—	—	—	—	—	—	900	1,210
—	—	3	—	—	—	—	—	—	—	2	5
—	—	715	—	—	—	—	—	—	—	125	1,596
—	130	62	—	—	—	151	27	185	—	77	666
—	9	40	50	40	—	—	—	—	—	39	178
—	—	12,300	—	—	—	—	400	—	—	940	19,600
—	—	—	—	—	—	—	240	—	—	2,280	10,880
—	477	1,545	—	—	—	—	—	182	—	68	2,272
—	—	—	—	—	—	—	—	—	—	16	324
—	—	1,300	—	—	—	—	—	—	—	220	1,520
—	—	20	—	—	40	—	—	4	—	10	80
21,300	6,300	6,300	—	—	—	7,800	—	6,800	—	2,300	57,400
—	—	—	—	—	—	—	—	26	—	6	32
—	—	—	—	—	—	—	—	—	—	66	566
—	11,570	1,782	—	—	—	—	—	1,980	—	466	16,298
—	2,243	—	—	—	—	1,099	—	2,482	—	1,338	8,453
—	127	170	—	—	—	510	—	320	—	197	1,539
345	—	55	—	—	2,600	—	—	—	—	—	3,000
—	—	—	—	—	—	—	—	—	—	—	66
—	—	—	—	—	—	660	—	—	—	93	846
—	—	—	—	—	—	46,127	682	—	—	3,066	58,679
400	—	—	—	—	—	—	—	—	—	150	1,000
—	3,200	3,400	—	—	—	3,200	—	4,200	—	2,000	26,100
—	—	—	—	—	—	—	—	—	—	61	478
—	—	—	—	—	—	—	—	—	—	61	766
—	—	—	—	—	—	—	—	—	—	684	19,884
—	—	1	—	2	—	—	3	2	—	8	66
—	—	—	—	—	—	16,573	—	—	—	123	16,696
—	—	—	—	—	—	—	—	—	—	(1)	(1)
—	—	—	—	—	—	1,462	—	—	—	—	22,089
—	—	5	—	—	—	10	—	—	—	27	124
—	—	6,782	—	—	—	—	—	—	—	378	7,160
—	—	—	—	—	—	337	—	—	—	75	536
—	—	—	—	—	—	—	—	—	—	1,399	34,720
—	—	—	—	—	—	—	—	—	—	—	6,086
—	—	—	—	—	—	3,912	—	—	—	290	4,227
—	—	286	—	—	—	—	—	—	—	—	286
—	—	—	—	—	1,414	—	1,470	—	—	6,183	46,154
—	—	—	—	—	—	934	—	—	—	27	976
—	—	—	—	—	—	220	—	—	—	1,263	7,068
—	—	—	—	—	—	966	—	—	—	76	1,042
—	—	—	—	—	—	1,393	—	—	—	236	2,040
—	—	—	—	—	—	46	—	—	—	411	1,084
—	—	—	—	—	—	299	—	—	—	7	324
—	—	—	—	—	1,466	—	—	—	2,530	—	5,475
—	—	—	—	—	380,098	—	—	80	6,840	22,089	882,700
—	—	—	—	—	3,429	—	1,709	—	7,342	4,800	21,223
—	—	—	—	—	—	—	—	—	—	15	1,083
—	—	—	—	—	560	—	320	3,296	1,098	217	6,076
—	—	—	—	—	—	—	—	—	—	—	—
800	—	—	—	—	8,000	—	—	300	—	300	9,000
181	—	5	—	—	—	—	—	—	—	21	242
95	—	—	65	—	35	—	—	130	—	195	570
—	—	—	—	—	—	—	1,086	—	—	62	2,570
875	—	—	—	—	—	—	—	—	—	1,066	16,127

TABLE 7.—WORLD PRIMARY MINERAL DEMAND IN 1974, WITH PROJECTED DEMAND IN 1985, AND CUMULATIVE DEMAND 1974–1985

COMMODITY	UNITS	1974			1985			CUMULATIVE 1974–1985		
		UNITED STATES	REST OF WORLD	WORLD	UNITED STATES	REST OF WORLD	WORLD	UNITED STATES	REST OF WORLD	WORLD
ALUMINUM	MILLION S.T.	6	11	17	11	22	33	93	181	274
ANTIMONY	THOUSAND S.T.	20	57	77	31	75	106	282	735	1,017
ARSENIC	THOUSAND S.T.	(1)	(1)	50	26	27	53	283	284	567
BARIUM	THOUSAND S.T.	930	1,752	2,682	1,425	3,200	4,625	13,000	27,000	40,000
BERYLLIUM	S.T.	206	159	365	400	250	650	3,600	2,300	5,900
BISMUTH	MILLION LB	2	4	6	4	8	12	30	66	96
BORON	THOUSAND S.T.	105	220	325	165	375	540	1,500	3,200	4,700
BROMINE	MILLION LB	363	281	644	595	467	1,062	5,280	4,305	9,585
CADMIUM	THOUSAND S.T.	6	13	19	9	18	27	81	169	250
CESIUM	THOUSAND LB	15	15	30	45	46	91	316	326	642
CHLORINE	MILLION S.T.	11	19	30	19	34	53	184	281	465
CHROMIUM	THOUSAND S.T.	560	2,136	2,696	700	2,800	3,500	6,980	27,200	34,180
COBALT	MILLION LB	20	46	66	27	58	85	263	600	863
COLUMBIUM	MILLION LB	5	20	25	11	33	44	111	293	404
COPPER	THOUSAND S.T.	1,958	5,068	7,026	2,700	10,000	12,700	26,000	84,000	110,000
FLUORINE	THOUSAND S.T.	631	1,666	2,297	1,360	3,840	5,200	12,200	28,400	40,600
GALLIUM	THOUSAND KG	7	5	12	13	9	22	111	77	188
GERMANIUM	THOUSAND LB	44	112	156	60	150	210	580	1,430	2,010
GOLD	MILLION T.OZ	4	22	26	7	29	36	60	286	346
HAFNIUM	S.T.	40	26	66	50	40	90	600	280	880
INDIUM	THOUSAND T.OZ	925	875	1,800	980	1,310	2,290	10,000	13,000	23,000
IODINE	MILLION LB	7	16	23	11	25	36	101	216	317
IRON ORE	MILLION S.T.	91	475	566	107	653	760	1,100	6,200	7,300
LEAD	THOUSAND S.T.	931	2,461	3,392	1,200	3,960	5,160	11,500	33,000	44,500
LITHIUM	THOUSAND S.T.	5	3	8	7	6	13	62	54	116
MAGNESIUM-METAL	THOUSAND S.T.	123	185	308	185	300	485	2,000	3,000	5,000
MAGNESIUM-NONMETALLIC	THOUSAND S.T.	1,019	4,400	5,419	1,800	5,848	7,648	14,000	55,000	69,000
MANGANESE	THOUSAND S.T.	1,492	8,728	10,220	1,700	13,100	14,800	17,000	117,000	134,000
MERCURY	THOUSAND FL	63	163	226	53	190	243	566	2,080	2,646
MOLYBDENUM	MILLION LB	76	124	200	102	204	306	990	1,810	2,800
NICKEL	THOUSAND S.T.	218	557	775	260	810	1,070	2,300	7,800	10,100
NITROGEN-COMPOUNDS	MILLION S.T.	13	40	53	19	58	77	170	550	720
NITROGEN-GAS & LIQUIDS	MILLION S.T.	9	18	27	12	23	35	110	230	340
PALLADIUM	THOUSAND T.OZ	673	977	1,650	975	1,700	2,675	9,000	15,000	24,000
PLATINUM	THOUSAND T.OZ	848	1,852	2,700	980	2,370	3,350	10,000	23,000	33,000
RARE EARTHS & YTTRIUM	THOUSAND S.T.	16	11	27	22	19	41	207	168	375
RHENIUM	THOUSAND LB	5	2	7	7	4	11	64	36	100
RHODIUM	THOUSAND T.OZ	51	109	160	75	120	195	700	1,300	2,000
RUBIDIUM	LB	1,210	1,000	2,210	1,800	1,600	3,400	16,600	14,300	30,900
SCANDIUM	KG	5	7	12	8	11	19	74	99	173
SELENIUM	THOUSAND LB	1,566	1,055	2,621	2,100	1,900	4,000	20,000	16,000	36,000
SILICON	THOUSAND S.T.	686	1,299	1,985	756	1,590	2,346	7,800	16,000	23,800
SILVER	MILLION T.OZ	124	250	374	160	321	481	1,600	3,200	4,800
STRONTIUM	THOUSAND S.T.	20	30	50	25	38	63	249	373	622
SULFUR	MILLION L.T.	11	38	49	15	50	65	143	508	651
TANTALUM	THOUSAND LB	1,980	1,100	3,080	2,300	1,700	4,000	24,000	16,000	40,000
TELLURIUM	THOUSAND LB	324	154	478	370	220	590	4,000	2,000	6,000
THALLIUM	THOUSAND LB	19	2	21	1	20	21	18	215	233
THORIUM	S.T.	80	40	120	90	60	150	900	900	1,800
TIN	THOUSAND L.T.	46	184	230	58	226	284	570	2,300	2,870
TITANIUM-METAL	THOUSAND S.T.	21	38	59	29	57	86	300	600	900
TITANIUM-NONMETALLIC	THOUSAND S.T.	525	1,038	1,563	790	1,830	2,620	7,400	16,000	23,400
TUNGSTEN	MILLION LB	15	70	85	27	87	114	233	868	1,101
VANADIUM	THOUSAND S.T.	8	20	28	16	31	47	132	285	417
ZINC	THOUSAND S.T.	1,464	4,936	6,400	2,120	6,720	8,840	19,200	63,200	82,400
ZIRCONIUM-METAL	THOUSAND S.T.	3	4	7	5	10	15	50	75	125
ZIRCONIUM-NONMETALLIC	THOUSAND S.T.	68	220	288	115	254	369	1,000	2,625	3,625
ASBESTOS	THOUSAND S.T.	846	3,680	4,526	895	5,629	6,524	9,900	50,800	60,700
CLAYS	MILLION S.T.	58	487	545	101	680	781	845	6,150	6,995
CORUNDUM	THOUSAND S.T.	1	10	11	1	13	14	10	131	141
DIAMOND-INDUSTRIAL	MILLION KT	25	50	75	37	80	117	352	714	1,066
DIATOMITE	THOUSAND S.T.	478	1,068	1,546	815	2,100	2,915	7,200	17,400	24,600
FELDSPAR	THOUSAND S.T.	833	1,667	2,500	1,150	3,050	4,200	11,300	24,900	36,200
GARNET	THOUSAND S.T.	20	9	29	26	14	40	255	138	393
GRAPHITE	THOUSAND S.T.	97	334	431	88	600	688	1,070	5,100	6,170
GYPSUM	MILLION S.T.	19	54	73	26	67	93	250	670	920
KYANITE	THOUSAND S.T.	(1)	265	(1)	250	500	750	1,710	4,050	5,760
LIME	MILLION S.T.	22	97	119	29	133	162	294	1,291	1,585
MICA-SCRAP & FLAKE	THOUSAND S.T.	124	122	246	185	125	310	1,700	1,400	3,100
MICA-SHEET	THOUSAND LB	7,160	25,000	32,160	4,000	11,300	15,300	58,300	182,600	240,900
PERLITE	THOUSAND S.T.	535	1,196	1,731	825	2,000	2,825	7,500	17,400	24,900
PHOSPHATE ROCK	MILLION S.T.	35	88	123	45	162	207	460	1,382	1,842
POTASH	MILLION S.T.	6	20	26	9	31	40	78	269	347
PUMICE	MILLION S.T.	4	11	15	6	16	22	57	147	204
QUARTZ CRYSTAL	THOUSAND LB	285	500	785	400	300	700	3,800	4,400	8,200
SALT	MILLION LB	49	123	172	75	248	323	700	2,000	2,700
SAND & GRAVEL	MILLION S.T.	978	5,863	6,841	1,390	9,100	10,490	13,000	82,000	95,000
SODA ASH	MILLION S.T.	7	17	24	10	28	38	94	236	330
STONE-CRUSHED	MILLION S.T.	1,041	4,029	5,070	1,550	6,600	8,150	14,300	58,600	72,900
STONE-DIMENSION	MILLION S.T.	2	36	38	2	40	42	20	421	441
TALC	THOUSAND S.T.	1,084	4,000	5,084	1,500	6,400	7,900	13,800	56,400	70,200
VERMICULITE	THOUSAND S.T.	324	233	557	500	450	950	4,500	3,700	8,200
ANTHRACITE	MILLION S.T.	5	201	206	5	165	170	55	2,000	2,055
BITUMINOUS COAL & LIGNITE	MILLION S.T.	553	2,691	3,244	918	3,080	3,998	8,100	31,900	40,000
NATURAL GAS	TRILLION C.F.	21	26	47	20	41	61	223	359	582
PEAT	MILLION S.T.	1	219	220	1	270	271	13	2,689	2,702
PETROLEUM	BILLION BBL	[2]6	15	21	[2]8	18	26	[2]75	185	277
SHALE OIL	MILLION BBL	—	55	55	110	110	220	330	900	1,230
URANIUM	THOUSAND S.T.	8	11	19	41	66	107	238	370	608
ARGON	THOUSAND S.T.	241	245	486	360	380	740	3,400	3,400	6,800
HELIUM	MILLION C.F.	[3]670	NA	NA	NA	NA	NA	NA	NA	NA
HYDROGEN	BILLION C.F.	2,570	5,050	7,620	4,345	8,700	13,045	38,100	75,800	113,900
OXYGEN	MILLION S.T.	16	39	55	32	55	87	280	510	790

NA NOT AVAILABLE.

[1] CERTAIN DATA ARE WITHHELD BECAUSE OF INDIVIDUAL COMPANY CONFIDENTIALITY.

[2] INCLUDES NATURAL GAS LIQUIDS.

[3] REVISED.

TABLE 9.—WORLD PRIMARY MINERAL DEMAND IN 1974, WITH PROJECTED DEMAND IN 2000, AND CUMULATIVE DEMAND 1974–2000

COMMODITY	UNITS		1974			2000			CUMULATIVE 1974–2000		
			UNITED STATES	REST OF WORLD	WORLD	UNITED STATES	REST OF OWRLD	WORLD	UNITED STATES	REST OF WORLD	WORLD
ALUMINUM	MILLION	S.T.	6	11	17	21	45	66	318	644	962
ANTIMONY	THOUSAND	S.T.	20	57	77	49	92	141	864	1,917	2,781
ARSENIC	THOUSAND	S.T.	(1)	(1)	50	36	20	56	675	696	1,371
BARIUM	THOUSAND	S.T.	930	1,752	2,682	1,886	5,100	6,986	35,600	83,200	118,800
BERYLLIUM		S.T.	206	159	365	1,150	475	1,625	14,900	7,700	22,600
BISMUTH	MILLION	LB	2	4	6	5	10	15	87	183	270
BORON	THOUSAND	S.T.	105	233	338	340	690	1,030	5,300	10,900	16,200
BROMINE	MILLION	LB	363	281	644	1,110	1,167	2,277	16,311	18,073	34,384
CADMIUM	THOUSAND	S.T.	6	13	19	13	28	41	236	508	744
CESIUM	THOUSAND	LB	15	15	30	200	225	425	1,940	2,131	4,071
CHLORINE	MILLION	S.T.	11	19	30	39	74	113	586	1,098	1,684
CHROMIUM	THOUSAND	S.T.	580	2,106	2,686	1,100	4,200	5,300	21,000	80,000	101,000
COBALT	MILLION	LB	23	46	69	43	94	137	793	1,774	2,567
COLUMBIUM	MILLION	LB	8	20	28	22	65	87	267	1,018	1,285
COPPER	THOUSAND	S.T.	1,963	5,263	7,226	4,200	18,000	22,200	78,000	275,000	353,000
FLUORINE	THOUSAND	S.T.	689	1,598	2,287	1,920	5,400	7,320	38,300	96,400	134,700
GALLIUM	THOUSAND	KG	7	5	12	32	15	47	442	252	694
GERMANIUM	THOUSAND	LB	44	112	156	81	200	281	1,600	4,020	5,620
GOLD	MILLION	T.OZ	4	22	26	15	43	58	234	832	1,066
HAFNIUM		S.T.	40	25	65	80	72	152	1,500	1,200	2,700
INDIUM	THOUSAND	T.OZ	825	975	1,800	1,540	1,760	3,300	30,000	35,000	65,000
IODINE	MILLION	LB	7	16	23	18	40	58	316	686	1,002
IRON ORE	MILLION	S.T.	91	475	566	129	1,000	1,129	2,700	18,800	21,500
LEAD	THOUSAND	S.T.	901	2,461	3,362	1,530	6,040	7,570	31,500	105,000	136,500
LITHIUM	THOUSAND	S.T.	5	3	8	14	15	29	217	213	430
MAGNESIUM-METAL	THOUSAND	S.T.	123	186	309	365	585	950	6,000	9,200	15,200
MAGNESIUM-NONMETALLIC	THOUSAND	S.T.	1,019	4,400	5,419	2,550	7,920	10,470	44,000	157,800	201,800
MANGANESE	THOUSAND	S.T.	1,492	8,728	10,220	2,130	20,400	22,530	46,000	362,000	408,000
MERCURY	THOUSAND	FL	53	183	236	47	222	269	1,300	5,300	6,600
MOLYBDENUM	MILLION	LB	76	124	200	183	383	566	3,320	6,140	9,460
NICKEL	THOUSAND	S.T.	219	557	776	385	1,205	1,590	7,400	22,100	29,500
NITROGEN-COMPOUNDS	MILLION	S.T.	13	40	53	29	97	126	520	1,700	2,220
NITROGEN-GAS & LIQUIDS	MILLION	S.T.	9	18	27	15	38	53	340	680	1,020
PALLADIUM	THOUSAND	T.OZ	673	877	1,550	1,340	3,730	5,070	26,000	55,000	81,000
PLATINUM	THOUSAND	T.OZ	848	1,852	2,700	1,225	3,665	4,890	27,000	70,000	97,000
RARE EARTHS & YTTRIUM	THOUSAND	S.T.	16	11	27	34	40	74	625	608	1,233
RHENIUM	THOUSAND	LB	5	2	7	9	6	15	171	105	276
RHODIUM	THOUSAND	T.OZ	51	109	160	125	160	285	2,200	3,500	5,700
RUBIDIUM		LB	1,210	1,000	2,210	3,000	3,000	6,000	52,500	48,200	100,700
SCANDIUM		KG	5	7	12	17	19	36	260	318	578
SELENIUM	THOUSAND	LB	1,565	1,056	2,621	3,020	4,450	7,470	59,000	63,000	122,000
SILICON	THOUSAND	S.T.	686	1,299	1,985	1,200	4,000	5,200	22,200	56,400	78,600
SILVER	MILLION	T.OZ	124	250	374	200	480	680	4,500	9,000	13,500
STRONTIUM	THOUSAND	S.T.	20	30	50	35	52	87	700	1,050	1,750
SULFUR	MILLION	L.T.	11	38	49	23	87	110	426	1,570	1,996
TANTALUM	THOUSAND	LB	1,980	1,100	3,080	4,600	3,400	8,000	81,000	54,000	135,000
TELLURIUM	THOUSAND	LB	324	154	478	510	260	770	11,000	5,000	16,000
THALLIUM	THOUSAND	LB	19	2	21	1	20	21	42	508	550
THORIUM		S.T.	80	40	120	250	360	610	3,500	3,900	7,400
TIN	THOUSAND	L.T.	46	184	230	84	262	346	1,400	6,100	7,500
TITANIUM-METAL	THOUSAND	S.T.	21	38	59	46	100	146	1,000	2,000	3,000
TITANIUM-NONMETALLIC	THOUSAND	S.T.	525	1,035	1,560	1,400	4,000	5,400	23,500	59,400	82,900
TUNGSTEN	MILLION	LB	16	69	85	49	125	174	790	2,480	3,270
VANADIUM	THOUSAND	S.T.	8	20	28	23	57	80	483	946	1,429
ZINC	THOUSAND	S.T.	1,464	4,936	6,400	3,050	9,300	12,350	57,300	182,200	239,500
ZIRCONIUM-METAL	THOUSAND	S.T.	3	4	7	12	32	44	180	450	630
ZIRCONIUM-NONMETALLIC	THOUSAND	S.T.	69	220	289	210	342	552	3,370	7,240	10,610
ASBESTOS	THOUSAND	S.T.	946	3,689	4,635	1,114	9,430	10,544	25,600	162,500	188,100
CLAYS	MILLION	S.T.	58	487	545	181	880	1,061	2,870	17,400	20,270
CORUNDUM	THOUSAND	S.T.	1	10	11	1	21	22	36	381	417
DIAMOND-INDUSTRIAL	MILLION	KT	25	50	75	70	150	220	1,157	2,411	3,568
DIATOMITE	THOUSAND	S.T.	479	1,066	1,545	1,765	5,400	7,165	26,400	71,300	97,700
FELDSPAR	THOUSAND	S.T.	833	1,667	2,500	2,000	6,000	8,000	35,100	89,500	124,600
GARNET	THOUSAND	S.T.	20	9	29	38	28	66	748	465	1,213
GRAPHITE	THOUSAND	S.T.	97	334	431	129	1,100	1,229	2,930	17,200	20,130
GYPSUM	MILLION	S.T.	19	54	73	35	90	125	680	1,860	2,540
KYANITE	THOUSAND	S.T.	(1)	266	(1)	800	1,050	1,850	6,820	15,130	21,950
LIME	MILLION	S.T.	22	97	119	43	186	229	825	3,701	4,526
MICA-SCRAP & FLAKE	THOUSAND	S.T.	124	122	246	215	160	375	4,400	3,600	8,000
MICA-SHEET	THOUSAND	LB	7,160	25,000	32,160	1,410	7,000	8,410	89,700	357,800	447,500
PERLITE	THOUSAND	S.T.	535	1,196	1,731	1,500	3,860	5,360	24,700	60,400	85,100
PHOSPHATE ROCK	MILLION	S.T.	35	88	123	69	387	456	1,359	5,449	6,808
POTASH	MILLION	S.T.	6	20	26	12	48	60	228	839	1,067
PUMICE	MILLION	S.T.	4	11	15	10	29	39	180	483	663
QUARTZ CRYSTAL	THOUSAND	LB	285	500	785	620	250	870	11,300	9,400	20,700
SALT	MILLION	S.T.	49	123	172	137	619	756	2,266	8,220	10,486
SAND & GRAVEL	MILLION	S.T.	978	5,963	6,941	2,090	15,200	17,290	39,000	263,000	302,000
SODA ASH	MILLION	S.T.	7	17	24	16	47	63	309	777	1,086
STONE-CRUSHED	MILLION	S.T.	1,041	4,029	5,070	2,500	12,300	14,800	43,900	197,200	241,100
STONE-DIMENSION	MILLION	S.T.	2	36	38	2	47	49	47	1,067	1,114
TALC	THOUSAND	S.T.	1,084	4,000	5,084	2,150	11,500	13,650	40,400	187,100	227,500
VERMICULITE	THOUSAND	S.T.	324	333	657	900	1,110	2,010	15,000	15,000	30,000
ANTHRACITE	MILLION	S.T.	5	201	206	6	130	136	130	4,280	4,410
BITUMINOUS COAL & LIGNITE	MILLION	S.T.	653	2,591	3,244	1,565	3,220	4,785	25,700	77,000	102,700
NATURAL GAS	TRILLION	C.F.	21	26	47	19	69	88	522	1,160	1,682
PEAT	MILLION	S.T.	1	219	220	2	360	362	40	7,320	7,360
PETROLEUM	BILLION	BBL	[2]6	15	21	[2]10	26	36	[2]198	520	718
SHALE OIL	MILLION	BBL	—	56	56	730	300	1,030	7,000	3,900	10,900
URANIUM	THOUSAND	S.T.	8	11	19	69	124	193	1,065	1,773	2,838
ARGON	THOUSAND	S.T.	241	245	486	660	670	1,330	11,100	11,100	22,200
HELIUM	MILLION	C.F.	[3]570	NA	NA	NA	NA	NA	NA	NA	NA
HYDROGEN	BILLION	C.F.	2,570	5,050	7,620	14,460	21,100	35,560	168,900	292,300	461,200
OXYGEN	MILLION	S.T.	16	39	55	62	86	148	900	1,500	2,400

NA NOT AVAILABLE.

[1] CERTAIN DATA ARE WITHHELD BECAUSE OF INDIVIDUAL COMPANY CONFIDENTIALITY.

[2] INCLUDES NATURAL GAS LIQUIDS.

[3] REVISED

TABLE 9.—U.S. SECONDARY METAL (OLD SCRAP) DEMAND IN 1950, 1960, 1970 AND 1974

COMMODITY	UNITS	1950			1960			1970			1974		
		TOTAL DEMAND	SECONDARY DEMAND		TOTAL DEMAND	SECONDARY DEMAND		TOTAL DEMAND	SECONDARY DEMAND		TOTAL DEMAND	SECONDARY DEMAND	
			QUANTITY	PERCENT OF TOTAL		QUANTITY	PERCENT OF TOTAL		QUANTITY	PERCENT OF TOTAL		QUANTITY	PERCENT OF TOTAL
ALUMINUM	THOUSAND S.T.	950	75	8	1,880	95	6	4,128	177	4	6,332	304	5
ANTIMONY	THOUSAND S.T.	34	19	56	32	20	63	33	18	56	43	23	53
BERYLLIUM	S.T.	130	—	—	380	—	—	380	2	1	309	—	—
BISMUTH	THOUSAND LB	1,000	NA	—	1,660	28	2	2,315	70	3	2,374	9	(1)
CHROMIUM	THOUSAND S.T.	277	46	16	381	28	7	529	67	13	825	86	11
COBALT	THOUSAND LB	6,136	136	2	10,080	240	2	16,256	60	(1)	23,403	270	1
COPPER	THOUSAND S.T.	1,757	486	28	1,836	480	28	2,076	504	24	2,406	483	20
GOLD	THOUSAND T.OZ	3,880	1,050	27	4,398	1,311	30	8,868	2,781	31	4,560	650	14
IRON	MILLION S.T.	95	33	35	97	32	33	117	33	28	138	51	37
LEAD	THOUSAND S.T.	1,136	435	38	1,088	470	47	1,385	500	38	1,532	601	39
MAGNESIUM	THOUSAND S.T.	25	5	22	56	4	7	99	3	3	128	6	5
MERCURY	THOUSAND FL	46	2	4	51	5	10	62	8	13	60	6	10
NICKEL	THOUSAND S.T.	108	3	3	149	27	18	205	49	24	284	65	23
PALLADIUM	THOUSAND T.OZ	150	21	14	414	34	8	737	198	27	886	213	24
PLATINUM	THOUSAND T.OZ	308	34	11	365	37	11	516	109	21	944	96	10
RHODIUM	THOUSAND T.OZ	14	NA	—	28	1	4	49	13	27	62	11	18
SILVER	MILLION T.OZ	185	50	27	187	48	26	129	56	43	178	54	30
TANTALUM	THOUSAND LB	150	NA	—	570	70	12	1,386	215	16	2,272	312	14
TIN	THOUSAND L.T.	97	34	35	81	22	27	73	20	27	57	11	19
TUNGSTEN	THOUSAND LB	6,797	200	3	11,086	200	2	16,700	500	3	16,208	600	4
ZINC	THOUSAND S.T.	1,221	74	6	1,024	68	7	1,374	72	5	1,539	75	5

NA NOT AVAILABLE.

[1] LESS THAN ONE-HALF UNIT.

TABLE 10.—U.S. FORECASTED SECONDARY METAL (OLD SCRAP) DEMAND IN 1985 AND 2000

COMMODITY	UNITS	1985			2000		
		TOTAL DEMAND	SECONDARY DEMAND		TOTAL DEMAND	SECONDARY DEMAND	
			QUANTITY	PERCENT OF TOTAL		QUANTITY	PERCENT OF TOTAL
ALUMINUM	THOUSAND S.T.	11,800	700	6	22,960	2,000	9
ANTIMONY	THOUSAND S.T.	60	29	48	90	40	44
BERYLLIUM	S.T.	430	—	—	1,170	20	2
BISMUTH	THOUSAND LB	4,220	120	3	4,720	220	5
CHROMIUM	THOUSAND S.T.	780	80	10	1,240	140	11
COBALT	THOUSAND LB	27,900	800	3	44,700	1,700	4
COPPER	THOUSAND S.T.	3,600	900	25	6,000	1,800	30
GOLD	THOUSAND T.OZ	7,800	900	11	17,000	1,700	10
IRON	MILLION S.T.	166	58	35	198	69	34
LEAD	THOUSAND S.T.	2,000	800	40	2,430	900	37
MAGNESIUM	THOUSAND S.T.	207	12	6	395	30	8
MERCURY	THOUSAND FL	62	9	15	58	11	19
NICKEL	THOUSAND S.T.	360	100	28	550	165	30
PALLADIUM	THOUSAND T.OZ	1,200	225	19	1,580	240	15
PLATINUM	THOUSAND T.OZ	1,285	305	24	1,440	215	15
RHODIUM	THOUSAND T.OZ	90	15	17	145	20	14
SILVER	MILLION T.OZ	225	65	29	310	80	26
TANTALUM	THOUSAND LB	2,600	300	12	5,300	700	13
TIN	THOUSAND L.T.	71	13	18	80	16	20
TITANIUM	THOUSAND S.T.	45	16	36	70	25	36
TUNGSTEN	THOUSAND LB	27,700	1,000	4	51,800	2,400	5
ZINC	THOUSAND S.T.	2,230	110	5	3,200	150	5

TABLE 11.—WORLD MINERAL RESERVES[1], 1974

COMMODITY	UNITS		UNITED STATES	OTHER NORTH AMERICA	SOUTH AMERICA	EUROPE	AFRICA	ASIA	OCEANIA	WORLD TOTAL
ALUMINUM	MILLION	S.T.	10	270	780	300	1,270	200	1,010	3,840
ANTIMONY	THOUSAND	S.T.	100	295	460	550	320	2,650	150	4,585
ARSENIC	THOUSAND	S.T.	800	500	1,000	500	500	300	200	3,800
BARIUM	MILLION	S.T.	35	5	6	25	10	15	3	100
BERYLLIUM	THOUSAND	S.T.	28	—	182	67	59	71	12	419
BISMUTH	MILLION	LB	25	17	13	18	1	58	—	131
BORON	MILLION	S.T.	30	—	10	20	—	30	—	90
BROMINE			A	A	A	A	A	A	A	A
CADMIUM	THOUSAND	S.T.	180	175	55	180	40	100	140	830
CESIUM	MILLION	LB	—	70	—	—	15	—	—	85
CHLORINE			A	A	A	A	A	A	A	A
CHROMIUM	MILLION	S.T	—	—	—	13	560	4	—	577
COBALT	MILLION	LB	—	1,130	—	500	2,294	—	1,480	5,404
COLUMBIUM	BILLION	LB	—	2	18	2	2	—	—	24
COPPER	MILLION	S.T.	90	60	130	60	60	30	20	450
FLUORINE	MILLION	S.T.	3	6	2	11	9	5	(2)	36
GALLIUM	MILLION	KG	1	7	4	9	45	3	41	110
GERMANIUM	THOUSAND	LB.	900	300	300	800	900	600	200	4,000
GOLD	MILLION	T.OZ	100	80	21	208	850	35	28	1,320
HAFNIUM			A	A	A	A	A	A	A	A
INDIUM	MILLION	T.OZ	10	13	4	11	3	4	4	49
IODINE	MILLION	LB	530	—	800	410	—	4,010	—	5,750
IRON ORE	BILLION	S.T.	4	12	20	40	3	11	10	100
LEAD	MILLION	S.T.	59	25	6	25	5	27	18	165
LITHIUM	THOUSAND	S.T.	327	100	10	201	100	3	3	744
MAGNESIUM			A	A	A	A	A	A	A	A
MANGANESE	MILLION	S.T.	—	2	44	755	1,005	47	160	2,013
MERCURY	THOUSAND	FL	480	370	30	3,425	30	625	—	4,960
MOLYBDENUM	BILLION	LB	6	2	2	2	(2)	1	(2)	13
NICKEL	MILLION	S.T.	(2)	10	5	6	1	6	32	60
NITROGEN			A	A	A	A	A	A	A	A
PALLADIUM	MILLION	T.OZ	(2)	4	—	—	100	80	—	184
PLATINUM	MILLION	T.OZ	(2)	4	(2)	—	248	45	—	297
RARE EARTHS & YTTRIUM	THOUSAND	S.T.	5,054	252	353	512	70	1,122	406	7,769
RHENIUM	THOUSAND	LB	2,600	410	1,520	800	2	6	—	5,340
RHODIUM	MILLION	T.OZ	(2)	(2)	—	—	14	3	—	17
RUBIDIUM	THOUSAND	LB	—	1,300	—	—	800	—	—	2,100
SCANDIUM	THOUSAND	KG	226	163	—	47	235	—	98	770
SELENIUM	MILLION	LB	77	52	96	51	51	26	17	370
SILICON			A	A	A	A	A	A	A	A
SILVER	MILLION	T.OZ	1,500	1,580	630	2,000	50	25	205	6,000
STRONTIUM	THOUSAND	S.T.	—	1,000	20	2,430	—	50	—	3,500
SULFUR	MILLION	L.T.	230	505	30	495	20	695	25	2,000
TANTALUM	MILLION	LB	—	7	8	11	100	18	5	149
TELLURIUM	MILLION	LB	18	12	22	12	12	7	4	87
THALLIUM	THOUSAND	LB	150	160	50	140	40	50	50	640
THORIUM	THOUSAND	S.T.	140	230	70	40	40	220	40	780
TIN	THOUSAND	L.T.	42	26	1,591	911	705	6,515	330	10,120
TITANIUM	MILLION	S.T.	32	57	69	43	23	132	20	376
TUNGSTEN	MILLION	LB	238	280	130	376	23	2,800	77	3,924
VANADIUM	THOUSAND	S.T.	115	—	240	8,075	2,000	100	150	10,680
ZINC	MILLION	S.T.	50	43	18	64	16	48	23	260
ZIRCONIUM	THOUSAND	S.T.	6,000	1,000	1,000	3,000	2,000	2,000	7,000	22,000
ASBESTOS	MILLION	S.T.	9	55	5	52	22	7	9	160
CLAYS			A	A	A	A	A	A	A	A
CORUNDUM			—	—	—	A	A	A	—	A
DIATOMITE	MILLION	S.T.	600	—	70	1,330	—	—	—	2,000
FELDSPAR	MILLION	S.T.	600	110	40	100	40	90	10	990
GARNET	THOUSAND	S.T.	700	—	10	500	1,000	10	10	2,230
GRAPHITE	MILLION	S.T.	(2)	1	(2)	4	1	4	(2)	10
GYPSUM	MILLION	S.T.	350	520	40	900	90	100	80	2,080
KYANITE	MILLION	S.T.	30	10	—	25	10	25	(2)	100
LIME			A	A	A	A	A	A	A	A
MICA-SCRAP & FLAKE			A	A	A	A	A	A	A	A
MICA-SHEET	MILLION	LB	(2)	—	2	—	4	27	—	33
PERLITE	MILLION	S.T.	200	5	—	765	—	20	10	1,000
PHOSPHATE ROCK	MILLION	S.T.	2,500	2	80	830	12,840	340	1,120	17,712
POTASH	MILLION	S.T.	200	5,000	10	5,515	20	245	10	11,000
PUMICE	MILLION	S.T.	1,250	50	15	650	30	40	30	2,065
SALT			A	A	A	A	A	A	A	A
SAND & GRAVEL			A	A	A	A	A	A	A	A
SODA ASH			A	A	A	A	A	A	A	A
STONE-CRUSHED			A	A	A	A	A	A	A	A
STONE-DIMENSION			A	A	A	A	A	A	A	A
TALC	MILLION	S.T.	150	10	5	60	5	90	10	330
VERMICULITE	MILLION	S.T.	100	—	5	5	75	5	—	190
ANTHRACITE	MILLION	S.T.	3,500	—	6	3,826	30	288	—	7,650
BITUMINOUS COAL & LIGNITE			A	A	A	A	A	A	A	A
NATURAL GAS	TRILLION	C.F.	257	58	65	876	186	633	71	2,146
PEAT			A	A	—	A	—	A	—	A
PETROLEUM	BILLION	BBL	[3]41	25	24	112	68	448	2	[4]720
SHALE OIL	BILLION	BBL	—	—	—	30	—	20	—	50
URANIUM	THOUSAND	S.T.	[5]267	204	—	81	291	—	340	1,098
ARGON			A	A	A	A	A	A	A	A
HELIUM	BILLION	C.F.	153	1	—	—	—	—	—	154
HYDROGEN			A	A	A	A	A	A	A	A
OXYGEN			A	A	A	A	A	A	A	A

A ADEQUATE.

[1] *IDENTIFIED RESOURCES* ARE SPECIFIC BODIES OF MINERAL-BEARING MATERIAL WHOSE LOCATION, QUALITY, AND QUANTITY ARE KNOWN FROM GEOLOGIC EVIDENCE SUPPORTED BY ENGINEERING MEASUREMENTS WITH RESPECT TO THE DEMONSTRATED CATEGORY, AND INCLUDE RESERVES AND SUBECONOMIC RESOURCES. *THE RESERVE* IS THAT PORTION OF THE IDENTIFIED RESOURCE FROM WHICH A USABLE MINERAL OR ENERGY COMMODITY CAN BE ECONOMICALLY AND LEGALLY EXTRACTED AT THE TIME OF DETERMINATION.

[2] LESS THAN ONE UNIT.

[3] INCLUDES NATURAL GAS LIQUIDS.

[4] REVISED IN 1975 TO 665 BILLION BARRELS.

[5] 780,000 TONS AT $30/LB (FEDERAL ENERGY RESOURCES COUNCIL, 6/15/76).

TABLE 12.—COMPARISON OF WORLD CUMULATIVE PRIMARY MINERAL DEMAND FORECASTS, 1974-2000, WITH WORLD IDENTIFIED MINERAL RESERVES

COMMODITY	UNITS		PRIMARY MINERAL DEMAND 1974-2000			MINERAL RESERVES, 1974			RATIO OF RECOVERABLE RESERVES TO CUMULATIVE DEMAND		
			UNITED STATES	REST OF WORLD	WORLD	UNITED STATES	REST OF WORLD	WORLD	UNITED STATES	REST OF WORLD	WORLD
ALUMINUM	MILLION	S.T.	314	648	962	10	3,830	3,840	—	5.9	4.0
ANTIMONY	THOUSAND	S.T.	864	1,917	2,781	100	4,486	4,586	0.1	2.3	1.6
ARSENIC	THOUSAND	S.T.	675	696	1,371	800	3,000	3,800	1.2	4.3	2.8
BARIUM	S.T.		36	83	119	35	65	100	1.0	.8	.8
BERYLLIUM	THOUSAND	S.T.	15	8	23	28	381	410	1.9	*	*
BISMUTH	MILLION	LB	87	183	270	26	105	131	.3	.6	.5
BORON	MILLION	S.T.	5	11	16	20	60	80	4.0	5.5	5.0
BROMINE	BILLION	LB	18	16	34	A	A	A	*	*	*
CADMIUM	THOUSAND	S.T.	238	506	744	180	680	860	.8	1.3	1.1
CESIUM	THOUSAND	LB	1,940	2,131	4,071	—	A	A	—	*	*
CHLORINE	MILLION	S.T.	558	1,086	1,644	A	A	A	*	*	*
CHROMIUM	MILLION	S.T.	21	80	101	—	577	577	—	7.2	5.7
COBALT	MILLION	LB	793	1,774	2,567	—	5,404	5,404	—	3.0	2.1
COLUMBIUM	MILLION	LB	367	1,018	1,385	—	24,000	24,000	—	*	*
COPPER	MILLION	S.T.	78	275	353	90	370	460	1.2	1.3	1.3
FLUORINE	MILLION	S.T.	38	96	134	3	35	38	.1	.4	.3
GALLIUM	THOUSAND	KG	442	252	694	1,000	A	A	2.3	*	*
GERMANIUM	THOUSAND	LB	1,600	4,080	5,680	900	3,100	4,000	.6	.8	.7
GOLD	MILLION	T.OZ	224	832	1,056	180	1,200	1,380	.8	1.4	1.3
HAFNIUM		S.T.	1,500	1,200	2,700	A	A	A	*	*	*
INDIUM	MILLION	T.OZ	30	35	65	10	38	48	.3	1.1	.8
IODINE	MILLION	LB	316	686	1,002	530	5,250	5,780	1.7	7.6	5.7
IRON ORE	BILLION	S.T.	3	19	22	4	96	100	1.3	5.1	4.5
LEAD	MILLION	S.T.	31	105	136	59	106	165	1.9	1.0	1.2
LITHIUM	THOUSAND	S.T.	217	213	430	327	417	744	1.5	2.0	1.7
MAGNESIUM	MILLION	S.T.	50	167	217	A	A	A	*	*	*
MANGANESE	MILLION	S.T.	46	362	408	—	2,013	2,013	—	5.6	4.9
MERCURY	THOUSAND	FL	1,300	5,300	6,600	450	4,480	4,930	.3	.8	.7
MOLYBDENUM	BILLION	LB	3	6	9	6	7	13	2.0	1.2	1.4
NICKEL	MILLION	S.T.	7	22	29	(2)	60	60	—	2.7	2.1
NITROGEN	MILLION	S.T.	950	2,290	3,240	A	A	A	*	*	*
PALLADIUM	MILLION	T.OZ	26	55	81	(2)	194	194	—	3.5	2.4
PLATINUM	MILLION	T.OZ	27	70	97	(2)	297	297	—	4.2	3.1
RARE EARTHS & YTTRIUM	THOUSAND	S.T.	625	608	1,233	5,054	2,715	7,769	8.1	4.5	6.3
RHENIUM	THOUSAND	LB	171	105	276	2,600	2,740	5,340	*	*	*
RHODIUM	MILLION	T.OZ	2	4	6	(2)	17	17	—	4.3	2.8
RUBIDIUM	THOUSAND	LB	55	46	101	—	2,100	2,100	—	*	*
SCANDIUM		KG	260	318	578	A	A	A	*	*	*
SELENIUM	MILLION	LB	59	63	122	77	293	370	1.3	4.7	3.0
SILICON	MILLION	S.T.	22	56	78	A	A	A	*	*	*
SILVER	MILLION	T.OZ	4,500	9,000	13,500	1,500	4,500	6,000	.3	.5	.4
STRONTIUM	THOUSAND	S.T.	700	1,050	1,750	—	3,500	3,500	—	3.3	2.0
SULFUR	MILLION	L.T.	426	1,570	1,996	230	1,770	2,000	.5	1.1	1.0
TANTALUM	MILLION	LB	81	54	135	—	149	149	—	2.8	1.1
TELLURIUM	MILLION	LB	11	5	16	18	69	87	1.6	*	5.4
THALLIUM	THOUSAND	LB	42	508	550	150	490	640	3.6	1.0	1.2
THORIUM	THOUSAND	S.T.	3	4	7	140	640	780	*	*	*
TIN	THOUSAND	L.T.	1,400	6,100	7,500	42	10,078	10,120	—	1.7	1.3
TITANIUM	MILLION	S.T.	25	61	86	32	344	376	1.3	5.6	4.4
TUNGSTEN	MILLION	LB	780	2,490	3,270	236	3,588	3,824	.3	1.5	1.2
VANADIUM	THOUSAND	S.T.	483	946	1,429	115	10,575	10,690	.2	*	7.5
ZINC	MILLION	S.T.	57	182	239	50	210	260	.9	1.2	1.1
ZIRCONIUM	MILLION	S.T.	3	8	11	6	16	22	2.0	2.0	2.0
ASBESTOS	MILLION	S.T.	26	162	188	9	151	160	.3	.9	.9
CLAYS	BILLION	S.T.	3	17	20	A	A	A	*	*	*
CORUNDUM	THOUSAND	S.T.	26	391	417	—	A	A	—	*	*
DIATOMITE	MILLION	S.T.	26	71	97	600	1,400	2,000	*	*	*
FELDSPAR	MILLION	S.T.	35	90	125	600	380	980	*	4.3	7.8
GARNET	THOUSAND	S.T.	748	465	1,213	700	1,530	2,230	.9	3.3	1.8
GRAPHITE	MILLION	S.T.	3	17	20	(2)	10	10	—	.6	.5
GYPSUM	MILLION	S.T.	680	1,860	2,540	350	1,700	2,050	.5	.9	.8
KYANITE	MILLION	S.T.	7	15	22	30	70	100	4.3	4.7	4.5
LIME	MILLION	S.T.	825	3,701	4,526	A	A	A	*	*	*
MICA-SCRAP & FLAKE	MILLION	S.T.	4	4	8	A	A	A	*	*	*
MICA-SHEET	MILLION	LB	80	366	446	(2)	33	33	—	.1	.1
PERLITE	MILLION	S.T.	25	60	85	200	800	1,000	8.0	*	*
PHOSPHATE ROCK	MILLION	S.T.	1,319	5,489	6,808	2,500	15,212	17,712	1.9	2.8	2.6
POTASH	MILLION	S.T.	228	839	1,067	200	10,800	11,000	.9	*	*
PUMICE	MILLION	S.T.	180	483	663	1,250	815	2,065	6.9	1.7	3.1
SALT	BILLION	S.T.	2	8	10	A	A	A	*	*	*
SAND & GRAVEL	BILLION	S.T.	39	263	302	A	A	A	*	*	*
SODA ASH	MILLION	S.T.	289	777	1,066	A	A	A	*	*	*
STONE-CRUSHED	BILLION	S.T.	44	197	241	A	A	A	*	*	*
STONE-DIMENSION	MILLION	S.T.	47	1,067	1,114	A	A	A	*	*	*
TALC	MILLION	S.T.	40	187	227	150	180	330	3.8	1.0	1.5
VERMICULITE	MILLION	S.T.	15	15	30	100	90	190	6.7	6.0	6.3
ANTHRACITE	MILLION	S.T.	130	4,280	4,410	3,500	4,150	7,650	*	1.0	1.7
BITUMINOUS COAL & LIGNITE	MILLION	S.T.	25,700	77,000	102,700	A	A	A	*	*	*
NATURAL GAS	TRILLION	C.F.	522	1,160	1,682	237	1,909	2,146	.5	1.6	1.3
PEAT	MILLION	S.T.	40	7,320	7,360	A	A	A	*	*	*
PETROLEUM[3]	BILLION	BBL	198	520	718	41	679	720	.2	1.3	1.0
SHALE OIL	BILLION	BBL	7	4	11	—	A	50	—	*	—
URANIUM	THOUSAND	S.T.	1,065	1,773	2,838	267	799	1,066	.3	.5	.4
ARGON	MILLION	S.T.	11	11	22	A	A	A	*	*	*
HELIUM	BILLION	C.F.	NA	NA	NA	153	1	154	NA	NA	NA
HYDROGEN	TRILLION	C.F.	169	292	461	A	A	A	*	*	*
OXYGEN	MILLION	S.T.	900	1,500	2,400	A	A	A	*	*	*

NA NOT AVAILABLE. A ADEQUATE. *RATIO OF 10 OR MORE.

[1] *IDENTIFIED RESOURCES* ARE SPECIFIC BODIES OF MINERAL-BEARING MATERIAL WHOSE LOCATION, QUALITY, AND QUANTITY ARE KNOWN FROM GEOLOGIC EVIDENCE SUPPORTED BY ENGINEERING MEASUREMENTS WITH RESPECT TO THE DEMONSTRATED CATEGORY, AND INCLUDE RESERVES AND SUBECONOMIC RESOURCES. *THE RESERVE* IS THAT PORTION OF THE IDENTIFIED RESOURCE FROM WHICH A USABLE MINERAL OR ENERGY COMMODITY CAN BE ECONOMICALLY AND LEGALLY EXTRACTED AT THE TIME OF DETERMINATION.

[2] LESS THAN ONE UNIT.

[3] UNITED STATES INCLUDES NATURAL GAS LIQUIDS.

TABLE 13.—COMPARISON OF WORLD CUMULATIVE PRIMARY MINERAL DEMAND FORECASTS, 1974–2000, WITH WORLD MINERAL RESOURCES[1], 1974

COMMODITY	UNITS	PRIMARY MINERAL DEMAND 1974–2000			IDENTIFIED MINERAL RESOURCES			RATIO OF IDENTIFIED RESOURCES TO CUMULATIVE DEMAND[2]		
		UNITED STATES	REST OF WORLD	WORLD	UNITED STATES	REST OF WORLD	WORLD	UNITED STATES	REST OF WORLD	WORLD
ALUMINUM (BAUXITE ONLY)[3]	MILLION S.T.	316	646	962	50	6,260	6,310	0.2	9.7	6.6
ANTIMONY	THOUSAND S.T.	864	1,917	2,781	130	5,450	5,580	.2	2.8	2.0
ARSENIC	THOUSAND S.T.	675	696	1,371	3,800	9,400	13,200	5.6	*	9.6
BARIUM	MILLION S.T.	36	83	119	230	770	1,000	6.4	9.3	8.4
BERYLLIUM	THOUSAND S.T.	15	5	23	80	1,136	1,216	5.3	*	*
BISMUTH	MILLION LB	87	183	270	36	257	293	.4	1.4	1.1
CADMIUM	THOUSAND S.T.	238	506	744	1,780	19,030	20,810	7.5	*	*
CHROMIUM	MILLION S.T.	21	80	101	2	1,155	1,157	.1	*	*
COBALT	MILLION LB	793	1,774	2,567	1,684	7,756	9,440	2.1	4.4	3.7
COLUMBIUM	MILLION LB	367	1,018	1,385	320	31,970	32,290	.9	*	*
COPPER[3]	MILLION S.T.	78	275	353	410	1,640	2,050	5.3	6.0	5.8
FLUORINE	MILLION S.T.	38	96	134	15	60	75	.4	.6	.6
GERMANIUM	THOUSAND LB	1,600	4,020	5,620	1,500	7,000	8,500	.9	1.7	1.5
GOLD	MILLION T.OZ	224	832	1,056	240	1,660	1,900	1.1	2.0	1.8
INDIUM	MILLION T.OZ	30	35	65	20	89	109	.7	2.5	1.7
IRON ORE	BILLION S.T.	3	19	22	18	197	215	6.0	*	9.8
LEAD	MILLION S.T.	31	105	136	119	211	330	3.8	2.0	2.4
LITHIUM	THOUSAND S.T.	217	213	430	927	1,178	2,105	4.3	5.5	4.9
MANGANESE	MILLION S.T.	46	362	408	74	3,526	3,600	1.6	9.7	8.8
MERCURY	THOUSAND FL	1,300	5,300	6,600	900	16,610	17,510	.7	3.1	2.7
MOLYBDENUM	BILLION LB	3	6	9	35	28	63	*	4.7	7.0
NICKEL	MILLION S.T.	7	22	29	15	108	123	2.1	4.9	4.2
PALLADIUM[3]	MILLION T.OZ	26	55	81	80	475	555	3.1	8.6	6.9
PLATINUM[3]	MILLION T.OZ	27	70	97	120	725	845	4.4	*	8.7
RHODIUM[3]	MILLION T.OZ	2	4	6	10	50	60	5.0	*	*
SELENIUM	MILLION LB	59	63	122	347	1,038	1,385	5.9	*	*
SILVER	MILLION T.OZ	4,500	9,000	13,500	5,700	16,930	22,630	1.3	1.9	1.7
STRONTIUM	THOUSAND S.T.	700	1,050	1,750	1,700	A	A	2.4	*	*
TANTALUM	MILLION LB	81	54	135	3	573	576	—	*	4.3
TELLURIUM	MILLION LB	11	5	16	82	245	327	7.5	*	*
TIN	THOUSAND L.T.	1,400	6,100	7,500	85	20,300	20,385	.1	3.3	2.7
TUNGSTEN	MILLION LB	780	2,490	3,270	958	10,400	11,358	1.2	4.2	3.5
ZINC	MILLION S.T.	57	182	239	130	1,530	1,660	2.3	8.4	6.9
ASBESTOS	MILLION S.T.	26	162	188	20	255	275	.8	1.6	1.5
GRAPHITE	MILLION S.T.	3	17	20	10	300	310	3.3	*	*
PHOSPHATE ROCK	MILLION S.T.	1,319	5,449	6,808	7,000	76,900	83,900	5.3	*	*
POTASH	MILLION S.T.	228	839	1,067	400	A	A	1.8	*	*
NATURAL GAS	TRILLION C.F.	522	1,160	1,682	[4]439	NA	NA	.8	NA	NA
PETROLEUM[5]	BILLION BBL	198	520	718	[6]74	NA	NA	.4	NA	NA
URANIUM	THOUSAND S.T.	1,065	1,773	2,838	356	1,508	1,864	.3	.9	.7

NA NOT AVAILABLE. A ADEQUATE. *RATIO OF 10 OR MORE.

[1] *IDENTIFIED RESOURCES* ARE SPECIFIC BODIES OF MINERAL-BEARING MATERIAL WHOSE LOCATION, QUALITY, AND QUANTITY ARE KNOWN FROM GEOLOGIC EVIDENCE SUPPORTED BY ENGINEERING MEASUREMENTS WITH RESPECT TO THE DEMONSTRATED CATEGORY, AND INCLUDE RESERVES AND SUBECONOMIC RESOURCES.

[2] EXCLUDES MINERALS WHERE U.S. AND REST OF WORLD RATIOS ARE MORE THAN 10.

[3] INCLUDES HYPOTHETICAL AND SPECULATIVE RESOURCES.

[4] MEASURED AND INFERRED RESERVES.

[5] UNITED STATES INCLUDES NATURAL GAS LIQUIDS.

[6] MEASURED, INDICATED, AND INFERRED RESERVES.

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Editor's note: The following section is taken from Wilfred Malenbaum, Carol Cichowski, Fathollah Mirzabagheri, and James Riordan, "United States Minerals Requirements in the Year 2000: Production Implications of Foreign Minerals Requirements in 2000," pp. 1-3, an annex to *Materials Requirements in the Year 2000,* Washington: National Commission on Materials Policy, Nov. 30, 1972.

I. RESEARCH SCHEME

In this report the demand for a material during any particular year – as of the turn of this century, in 2000 – is derived as the product of two components: the level of overall economic activity at that time and the intensity-of-use of the material at that level of overall activity. The task of estimating materials requirements in 2000 thus divides into one of estimating national product and one of estimating the amount of material needed in the production of one unit (in dollars) of national product in 2000. The first component (level of national activity) will of course be the same for all materials. This contributes some consistency among estimates for different materials – a matter of particular concern when estimates are presented for a remote date. The second component (intensity-of-use) has a basic technological dimension. For it must give emphasis to the role of changing methods and alternative materials in the process of production as economic activity evolves over time. Both components must rest upon the historical record in all parts of the world treated here. Past data for consumption (production + imports – exports – usually termed "apparent consumption") are readily separated into these two elements.

The world is considered in 10 subdivisions selected for relevance to the present concern – estimates for non-U.S. demand, patterns of demand change in developing lands, for example – with enough homogeneity in a subdivision to permit common assumptions about changes in intensities-of-use of materials and in rates of total economic growth. The following "regions" are used (and designated by number in the tabular presentation):

1. Western Europe – OECD countries, plus Greece, Portugal, Spain, Turkey
2. Japan
3. Other Developed Lands – Australia, Canada, Israel, New Zealand, South Africa
4. Union of Soviet Socialist Republics
5. Eastern European Countries – bloc countries plus Albania, Yugoslavia
6. Africa – minus South Africa
7. Asia – minus Israel, Japan, Mainland China and related areas
8. Latin America
9. China – plus Mongolia, North Korea, North Vietnam

Commodity estimates for the tenth unit, the United States, are not presented explicitly in the body of the present report although considerable use is made here of the well-documented United States record in materials.[1]

With respect to gross domestic product – the measure of overall economic activity adopted for this report – the initial step was selection of a recent base year in which comparable total output estimates (in U.S. dollars) could be made available for each of the units (regions) into which the world was subdivided. Indexes of comparable output were then assembled for the same areas over the years since 1950. Finally, for each region, a single average rate of growth was determined to represent the expected developments in total economic growth over the 30-year period from 1970 to 2000. This was not a task of national income construction; rather it was an exercise in the theory of national growth. Its main *statistical* component was the selection of an appropriate average rate of growth to represent what inevitably will be the *range and variations* in growth rates that each subdivision of the world can expect to experience over some three decades. Thus despite unemployment and despite underutilization of plant capacity in the United States, the economy has even in the very recent past experienced an annual real growth rate of 0% (1970) and of 2.7% (1971). It did experience a few rates above 5% in some years of the late 1960's and a rate of about 6% is now anticipated for 1972. Whatever progress man and society have made in their capacity to generate economic advance – and there is clear evidence of upward movement in average rates of growth over periods of years – all subdivisions of the world must anticipate short-period fluctuations in these rates. The rate projected for the 30-year period until the year 2000 obviously needs to allow for such variations.

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[1] A separate *Annex* provides comparable figures for materials requirements in the year 2000 for the United States (plus Puerto Rico and island possessions). These figures are derived in a manner consistent with the non-U.S. estimates in this report.

The estimates for this component of the requirement figures are discussed and presented in section II of this report.

Intensity-of-use data for each material are presented on a total domestic product basis, separately for the subdivisions of the world listed above. Such figures differ significantly among the world's regions, as they usually do for each subdivision over time. For intensity-of-use of a material depends upon geography, industrialization, economic advancement and other factors for which the world offers a varied pattern. Many of these factors change over time – notably industrial and economic development. Indeed, use of materials can be associated with the specific products and services a nation produces – the output of automobiles, or the miles people travel in a year, or the extent of electrification, as examples. Every materials use figure might be accounted for fully in such itemized outputs, but this would certainly be a major research undertaking even for the relatively few countries where statistics on such use are available. Any projected use-intensity for each group of nations in a world total would require very many specific assumptions about future product use. Instead reliance is placed here upon more general attributes of the demand for materials, derived from past relationships and the theory that helps explain them.

Trends and patterns of past intensity-of-use data were analyzed; they presented several possibilities for future developments. On occasion the past record suggested a more or less direct extrapolation to the year 2000. Much more common was evidence of a reversal pattern: intensities increased over a period and then began to decline. There was evidence of an association with the level of income. Indeed, the intensity-of-use data for all regions of the world together do reveal some systematic patterns. Below, in section III, we discuss specific relationships of materials use and per capita income. We discuss also the evidence on changes in use-intensities with actual changes in goods and services (in which materials are used) as per capita income grows, with new technologies that make for more efficient materials use, and with the possibilities of substitution among materials as technology, demand, and supply alter relative materials prices. All these offered guides for determining the appropriate intensity level for 2000, as did the experience of commodity specialists and the extensive analytic and descriptive literature on materials use. As in the case of growth in national product, economic theory helped here also – particularly with respect to doctrine on commodity substitution under conditions of demand and technological change, and with the price and policy adjustments related to these changes.

In the last analysis, however, systematic consideration of these guides and possibilities had to be supplemented by the judgment of the research worker. For the present report this subjective input was the responsibility of one individual, the principal researcher on this project. As with the "answers" for rates of national growth to the year 2000, the "answers" on intensity-of-use of each material in that year reflected consistent judgments, conditioned by a vast assembly of pertinent data (including oral and written expert information), the economic rationale of past performance, and theories of economic equilibrium, change, and growth.

The estimates for this second component of the requirements figures, by commodity and by subdivision of the world, are discussed more fully and presented in section III below.

Materials requirements for 2000, with comparable statistics on historical use, are in section IV. The tabular presentation also includes series for consumption per person for each commodity in each of the nine subdivisions of the non-U.S. world. Elasticity coefficients have also been computed, showing percentage change in consumption of each material, 1966-69 to 2000, relative to percentage growth in total domestic product over this period. Historical comparisons, 1951-55 to 1966-69, are also given. The "answers" thus permit ready comparisons of materials consumption over time and among important subdivisions of the world.

Finally, we stress that the two components of the research program rest on a common basic assumption: the growth of nations has an *internal dynamic*. That is, growth is not governed by supply limitations of any specific input materials nor is it limited by any inelasticity of total output imposed by supply or demand of materials. This assumption made it possible to project national and world economic growth in one part of the research effort without regard to the materials position appraised in the other part of the study. A nation meets its needs for materials in the pursuit of its economic, social, and political objectives. This assumption is consistent with the theory of economic growth held to be relevant to experience in the modern world of the past two centuries or so; it is discussed further in II below. In addition, the research on past materials consumption, and indeed the results developed in III below, are themselves testimony to the diversity of materials usage in the modern world. As relative supplies shift, as demands alter, as techniques of use change, as price ratios vary, rules of operation are altered. These adjustments are the tools by which man and society obtain and use materials they need. This is how it has been; the extensive past experience augurs well for the future.

But the tools must cope with what promise to be progressively greater tasks. Poor nations must have higher levels of living; populations grow at record rates; minerals production generates environmental hazards. There is need for continuous and imaginative study of the alternatives in supply and requirements of materials, and for governmental and intergovernmental policy and actions based on such study. Still, the past record tells us that such efforts can be undertaken with the expectation that the world's materials resources can continue to *serve* the world's aspirations for social and economic progress. The world's materials resources will *govern* such objectives only if research and policy needs are neglected.

Editor's note: The following section is taken from Wilfred Malenbaum et al., "World Demand for Raw Materials in 1985 and 2000," an unpublished report prepared for the National Science Foundation under grant no. 75-23687, Oct. 1977, pp. 18–51.

II. The Research Scheme

What factors determine the quantity of any specific industrial raw material a nation will use up over a given year? Given the need for answers for future time periods, these factors must themselves permit more straightforward and justifiable extrapolations than would the dependent variable (the amount of raw material used up) itself. Three factors were selected here as the best determining variables. Thus to estimate ${}_iD_t$, the use of material i in the year t, there is need for (1) the total value of final goods and services produced in the year t by a nation's endowments (GDP_t); (2) the nation's population in that year (p_t); and (3) what may be called the intensity-of-use of i in year t (${}_iI\text{-}U_t$) defined so:

$${}_iI\text{-}U_t = \frac{{}_iD_t}{GDP_t} .$$

Obviously, $${}_iD_t \equiv \left(GDP_t\right)\left({}_iI\text{-}U_t\right) = GDP_t \frac{{}_iD_t}{GDP_t}$$

Following is a discussion of the nature of each factor's relationship to ${}_iD_t$ and of the interrelationships among the three factors. In particular, the discussion examines the relevance of a tautological formula in integrating the three factors to yield ${}_iD_t$.

1. GDP_t. Raw materials are intermediate-type inputs in the production process. Therefore, "using up" a raw material, i in t, can only mean its use in producing a nation's final goods and services during t. Ordinarily there is essentially no demand for i as end-product in itself; even inventory demand for carryovers of i reflects a time dimension of the

same derived demand as the demand for i's current use in final goods. Hence, some measure of total national product, i.e., the value of all final goods and services produced by a nation's productive resources over a year's period, must be an important factor determining materials use. While there are arguments in favor of some net rather than gross measure of this product, the latter is used here. In any event, the GDP measure has greater statistical reliability and much broader availability. A negative consideration is the possible distortion of the intensity-of-use measure in periods of heavy stockpiling associated with marked price changes of some raw materials. This is revealed in actual data (e.g., in Japan in the early 1970s), but such inventory changes are usually recorded, and their distortions on the intensity measure can generally be taken into account ...

Most projection schemes for materials demand do use this association with GDP. One can examine past relationships in this regard: *ex post*, the direction of determination may not be relevant, but not so for the *ex ante* purpose of prime concern here. For we use estimated GDP_{1985} and GDP_{2000} as one key determinant of ${}_iD$ in each of these two years. If material i is itself a significant determinant of GDP, the argument is circular and probably invalid. Currently, limits-to-growth themes have some vogue, although probably less so than was the situation in 1972 and 1973. The present paper does not accept the view that GDP_t for t over a long period of years will be determined by the availability of any material i. It argues rather (III below) that for such future years GDP_t levels will be primarily the consequence of decisions and actions of man, whatever the availability of specific materials. Both theoretical and empirical considerations prompt this view, and these considerations have dictated the quantitative GDP growth projections presented in this report.

The first determining factor then will be each regional unit's level of national product, usually as GDP_t. And in the nature of materials use, one can hypothesize that upward GDP movement, other factors constant, will contribute to upward ${}_iD_t$ movement.

Given the goal of projecting ${}_iD_t$ for a range of i's, it may be noted here that in the formula, GDP_t is the same, whatever i. This constancy contributes an element of consistency in the twelve i's of this study as projections are made for future t's, i.e., 1985 and 2000.

2. Population (p_t). The population role in ${}_iD$ is very different from that of GDP; on the whole, the relationship of population change to ${}_iD$ is more complex than is the role of GDP. Nonetheless, many projections of ${}_iD_t$ do assume a positive population role, essentially parallel to the positive GDP role.[1] It is obvious that a very wide gap persists between

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[1] For example, two important and significant forecast studies, one by the U.S. Bureau of Mines (Mineral Facts and Problems, 1970, GPO, Washington, D.C.), and the other by Resources for the Future (Population, Resources and the Environment: A Report to the U.S. Commission on Population Growth and the American Future, R.G. Ridker, ed., GPO, Washington, 1972) seem to assume cumulative positive relationships for these two independent variables: ${}_iD$ increases when GDP or population increases. This is shown explicitly in summary results presented by D.B. Brooks and P.W. Andrews, "Mineral Resources, Economic Growth and World Population," Science, 5 July 1974, p. 15.

population shares and resource use shares. Thus, at mid-century the rich world, with less than one-third of the world's population used about 95 percent of the raw materials. The poor world ratio of materials use did move up dramatically between 1950 and 1970. But this was due not to their population growth but to their GDP growth. Despite the rapid population growth in these lands, GDP growth rates were still higher over those decades.

Indeed, a relevant determining element turns out to be GDP/$_{\text{population}}$, so that the relationship between changes in materials use and population change is usually inverse. This relationship is best discussed in connection with the third factor basic to ${}_iD_i$ determination in the present study.

3. Intensity-of-Use $\left({}_iI\text{-}U_t\right)$. This measures the physical amount of i used up per unit of GDP in any particular period. Comparisons among countries make it necessary to present GDP magnitudes in a single currency (U.S. $ here); comparisons over time require a constant price level (1971 here). Both the population factor and the intensity measure serve as correctives to the GDP contribution to estimates of ${}_iD_t$. "Population" corrects for the new number of people sharing a GDP level at time t. "Intensity" adjusts for the new structure of GDP as its product composition differs at a t level, and as new technology and new cost structures alter the process of GDP creation. The application of the intensity ratio in the study of materials use has begun to be explored only in very recent years.[1]

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[1] See the observations on this point in Brooks and Andrews, ibid., pp. 15-16.

Perhaps the present effort is the most comprehensive. As the discussion in IV makes clear, there is an analytic case for further and continuing research exploration of the relationship between physical inputs of intermediate materials and real value of final goods and services.

Several aspects of this I-U measure are noteworthy. First, it is readily available over past years, given statistics on a nation's use of i. Second, the very concept of an input and output relationship has a technological dimension. It must reflect changes in use and efficiency of inputs to yield outputs, with account taken of changes in techniques (for input or output) and changes in market relationships associated with supply, demand and public policy bearing on inputs and outputs. Third, and of particular interest, the historical evidence on use-intensity suggests there are patterns of behavior of the measure. And these patterns may be identified with underlying theory and empirical time observation. Indeed, it is this systematic behavior of the measure that constitutes the big promise for its usefulness in demand analysis for raw materials.

Among the observed patterns are those which emerge when intensity-of-use in a region is associated with per capita GDP over a period of years. With such a relationship our "formula," ${}_iD_t = GDP_t \frac{{}_iD_t}{GDP_t}$, incorporates all three of the determining factors considered here. There is of course a significant body of facts and of theory on the subject of the growth of nations. While theory and policy on this matter are today in some state of controversy, national growth does constitute an area central to the social science professions. Quite separate from this doctrine on GDP, the second term (the ratio that measures intensity-of-use) may well have significance beyond what its numerator and denominator has separately. Intensity-of-use could thus have an empirical and theoretical life of its own. In this event, the tautology converts into a useful analytic tool.

This is the context in which the present research scheme rests upon the identity formulation: changes in the three determining factors can be related to changes in levels of materials use.

As indicated in the Introduction, attention will be given to the following materials, ferrous and nonferrous in turn, and numbered as they appear in tabular presentations and discussions:

1. crude steel
2. iron ore
3. nickel
4. manganese
5. chrome
6. cobalt
7. tungsten
8. copper
9. aluminum
10. platinum group
11. zinc
12. tin

Again, as in the 1973 report, analysis will continue to consider the world in ten subdivisions, with subtotals (1) for the U.S. and non-U.S. regions, and again (2) for rich nations and poor nations. This "regionalization," perhaps more functional than geographic, represents an effort to differentiate within these large two world subdivisions. Each of the ten groups is considered to have a high enough degree of homogeneity to justify common assumptions with respect to changes in intensity-of-use of raw materials and in rates of total economic growth. Where individual country patterns reflect significant differences, some supplementary study was undertaken. While for some materials (nickel and the platinum group, for example) data availability required some regional changes in the analysis (and this is of course evident in the text) there was no analytic reason to adopt alternative subcategorization in the present study. The major use centers for materials are treated as a single region (U.S., Japan, U.S.S.R., for example), or as a fairly unified total of countries (Western Europe, Eastern Europe); similarly, with respect to use behavior in the large components of the poor lands. Consideration of ten "regions" as against a larger number undoubtedly cost some detail in the results, but the study justifies the belief that it did not introduce arbitrary elements in the demand projections.

These regions are defined as follows, again with number designations for textual presentation:

1. Western Europe - OECD countries in Europe
2. Japan
3. Other Developed Lands - Australia, Canada, Israel, New Zealand, South Africa
4. Union of Soviet Socialist Republics
5. Eastern European Countries - Soviet Bloc countries plus Albania, Yugoslavia
6. Africa - minus South Africa
7. Asia - minus Israel, Japan, Mainland China and related areas
8. Latin America
9. China - plus Mongolia, North Korea, North Vietnam
10. United States - plus Puerto Rico and overseas islands
11. World - Sum 1-10

12. Non-U.S. World - Sum 1-9

13. Poor Nations - Sum 6-9

14. Rich Nations - Sum 1-5, 10

Before presenting specific estimates for GDP and $^{GDP}/_{population}$ in 1985 and 2000, and for $\frac{{}_iD_t}{GDP_t}$ for each i in those years, some observations are made on the procedures employed. In all these measures, the historical record was initially assembled from 1951 to 1975 and where available from 1934-1938. Essentially all national product data and all population data were taken from United Nations sources. The output was converted to U.S. dollars in 1971 prices on the basis of exchange rate data. Estimation was undertaken for areas and periods only when they were not reported by the United Nations. For the U.S.S.R. and for Mainland China, for which official data are not conceptually comparable with much of the remaining world, the adjusted figures prepared by specialist groups were used. Specifically, for the U.S.S.R., the gross product data are from reports prepared for the Joint Economic Committee of the U.S. Congress over the past decade; for China the same source has publications at least from 1972. For the most part, the historical record was examined in the form of five-year averages, with recourse to individual years only to trace patterns of marked change within a five-year period, a problem that arose especially for regions composed of different countries not usually analyzed as a single unit, e.g., "Other Developed Lands."

On the population front, the U.N. data alone were the source of all the numbers in the present study.

The basic historical tables on GDP and GDP per person, more or less to date, are thus these five-year averages in 1971 U.S. dollars. Again, they provide the available factual record. Projections for 1985 and 2000 were made entirely by estimating two average growth rates for GDP, one for the ten-plus years to 1985 from the 1971-75 average, and the other for the 25-plus years to 2000. While an important consideration in these estimated growth rates for GDP was the record of growth rates of past years, the basic factor was the expectation derived from underlying doctrine on economic expansion. With respect to population growth to 1985 and to 2000, reliance was placed on the most recent working paper of the Population Division of the United Nations Secretariat.[1] The GDP/population estimates for 1985 and 2000 were then derived.

The 1985 and the 2000 statistics are not statistical extrapolations. One could perhaps argue that modern nations have the knowledge and the capacity to generate higher GDP growth rates than they had a generation or so back. The evidence from 1951 does not reveal that these potentials have become realities, nor is there much basis today for arguing that such knowledge and capacity will assure higher rates in the future. Thus, in only two of the ten regions was the average growth rate for 1966-1975 higher than for 1951-1960. In any event, the actual record is for large year-to-year variations in most regions. Moreover, there is increasing appreciation that the determinant forces for growth lie in the aspirations and commitment to economic expansion on the part of public and private leaders, much more than in resources endowment and supply and in technology. On the one hand, this analytic view plays down the role of materials limits to growth, and thus enhances the prospect for future progress. On the other hand, this view stresses the role of leadership and its determination to cope with whatever deterrents impede achievement of a nation's growth goals. Recent developments in this respect cannot be judged propitious in many of the world's regions, a matter discussed in B below.

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[1] In particular, Population by Sex and Age for Regions and Countries, 1950-2000, As Assessed in 1973: Medium Variant, ESA/P/WP60, 25 February 1976.

While the intellectual content of the economic development process remains a matter of some controversy today, the actual record of growth in various parts of the world in the years to the early 1970s did lend support to the decisive role of quality inputs in growth achievement in rich lands. And the relative unimportance of the returns to quality inputs in poor lands was held most responsible for their uncertain economic performance. The accompanying diagram (Figure A-1) reflects these contrasts impressionistically.[1] It suggests that the growth returns to effective leadership-for-growth became increasingly more important in total growth of rich lands, as against the growth returns from more labor and more capital of constant quality. On the poor nation side, limited performance from quality inputs resulted in much lower roles of growth than supplies of capital resources and of number of workers could have permitted.

The course of development in both of these world components was interrupted by the world recession of the mid-1970s. In some measure, this setback was itself a reflection of a leadership crisis. But even if more

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[1] For a brief summary account of the underlying economic arguments, with references to the theoretical literature and an illustration in the case of India, see Wilfred Malenbaum, Modern India's Economy, Merrill, 1971, pp. 117-23.

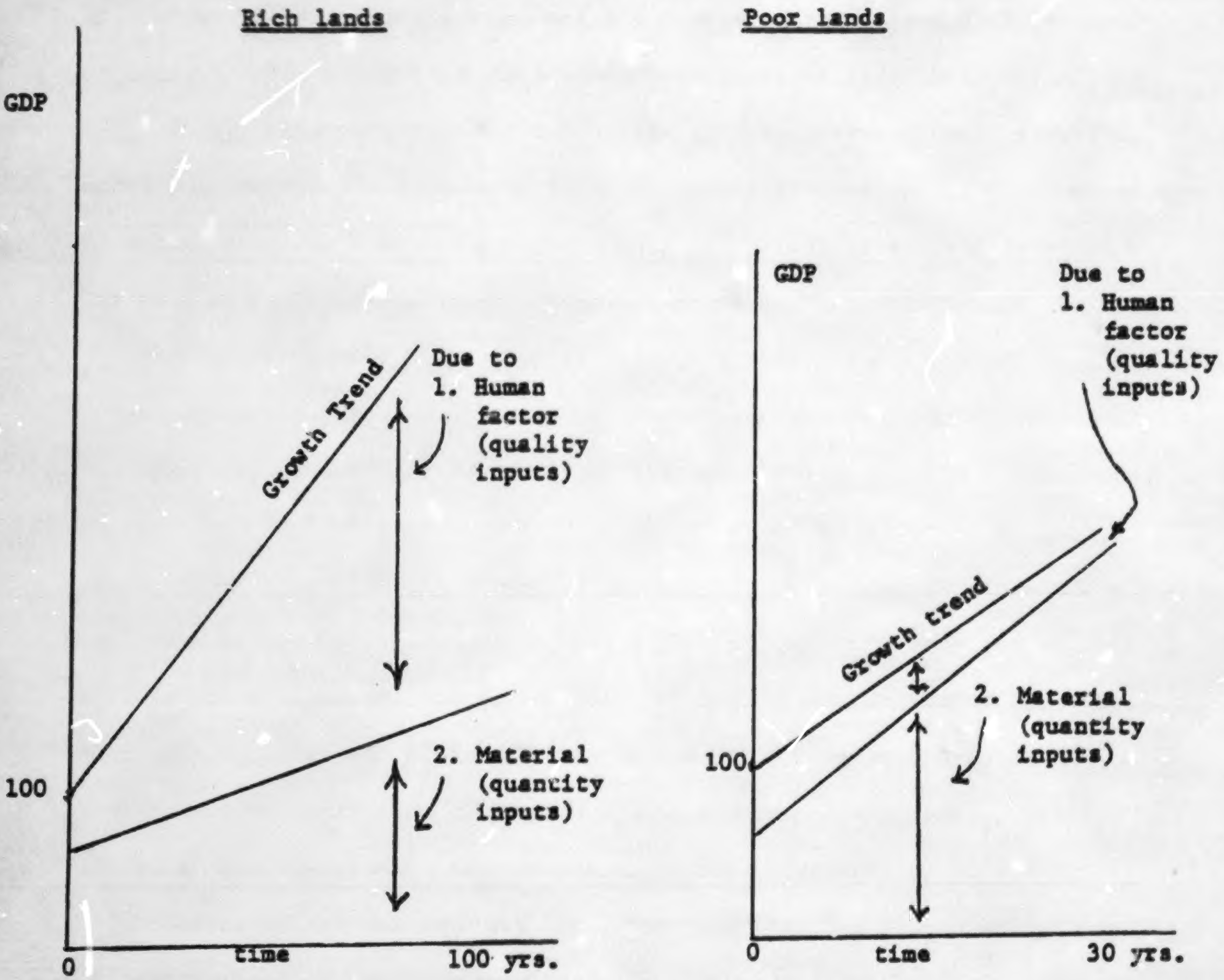

Rich lands
GDP
Growth Trend
Due to
1. Human factor (quality inputs)
2. Material (quantity inputs)
100
0
time
100 yrs.
Poor lands
GDP
Due to
1. Human factor (quality inputs)
Growth trend
2. Material (quantity inputs)
100
0
time
30 yrs.

Fig. 2-1.--Relative Economic Growth Trends in Rich and Poor Lands due to Human Factors (Quality Input) and Material Factors (Quantity Input): A Schematic Representation, 1870-1973, Rich Lands; 1945-1973, Poor Lands.

emphasis is given to the role of the natural resource crises of the 1970s--to food, raw materials, petroleum--recovery has been hampered by quality input difficulties stemming from diffusion of quality inputs in rich lands and from diversion of interest from quality to quantity inputs in poor lands. Both prompt conservative expectations of long-term rates of economic growth, in rich as well as poor nations (III below).

Intensity-of-use data were assembled for essentially the same time intervals, 1951-75, with occasional data for 1934-38. They are of course presented here on the same regional bases as were GDP, population and GDP/population. Again, our materials use data are from the accepted world sources, notably national and international organizations in the public sector, e.g., U.S. Bureau of Mines, U.K.'s Statistical Summary of the Mineral Industry, U.N. Department of Economic and Social Affairs, and occasional specialized private groups associated with producing and processing interests (e.g., Germany's Metal Statistics). Specific sources appear on text tables. Insofar as possible, "use" was considered on the basis of raw materials as such. It was not extended to the material embodied in finished product form. The consumption concept was "apparent consumption," or production minus exports plus imports plus changes in stocks. Again, the data are broadly available, with exceptions already noted and amply referenced in the report. However available in published form, much of the materials data have not previously been assembled in consistent sets of regional tables on a world basis. The intensity-of-use ratio was of course obtained by division with the GDP figures discussed earlier.

It is this measure that receives major research attention in this study. As already indicated, the very concept has a technological ring.

It is apparent that the values of these measures differ significantly as among the world's regions, as they do in each region over time. Presumably, the measure for each i depends upon industrialization, economic sophistication, resource position and other factors for which the world does offer a wide range of patterns. And these factors change over time, notably with industrial and economic development. Use of material inputs must be associated with the specific products and services a nation produces--the output of automobiles, or the miles people travel in a year, or the extent of electrification, as examples. And every measure of materials use should be accounted for fully in such itemized outputs. To do this would certainly be a major research undertaking even for the relatively few countries where statistics on use detail are available. Any projected use-intensity would require many specific assumptions about future product use. Hence, reliance needs to be put on more general attributes of the demand for materials, derived from past relationships and the theory that helps explain them.

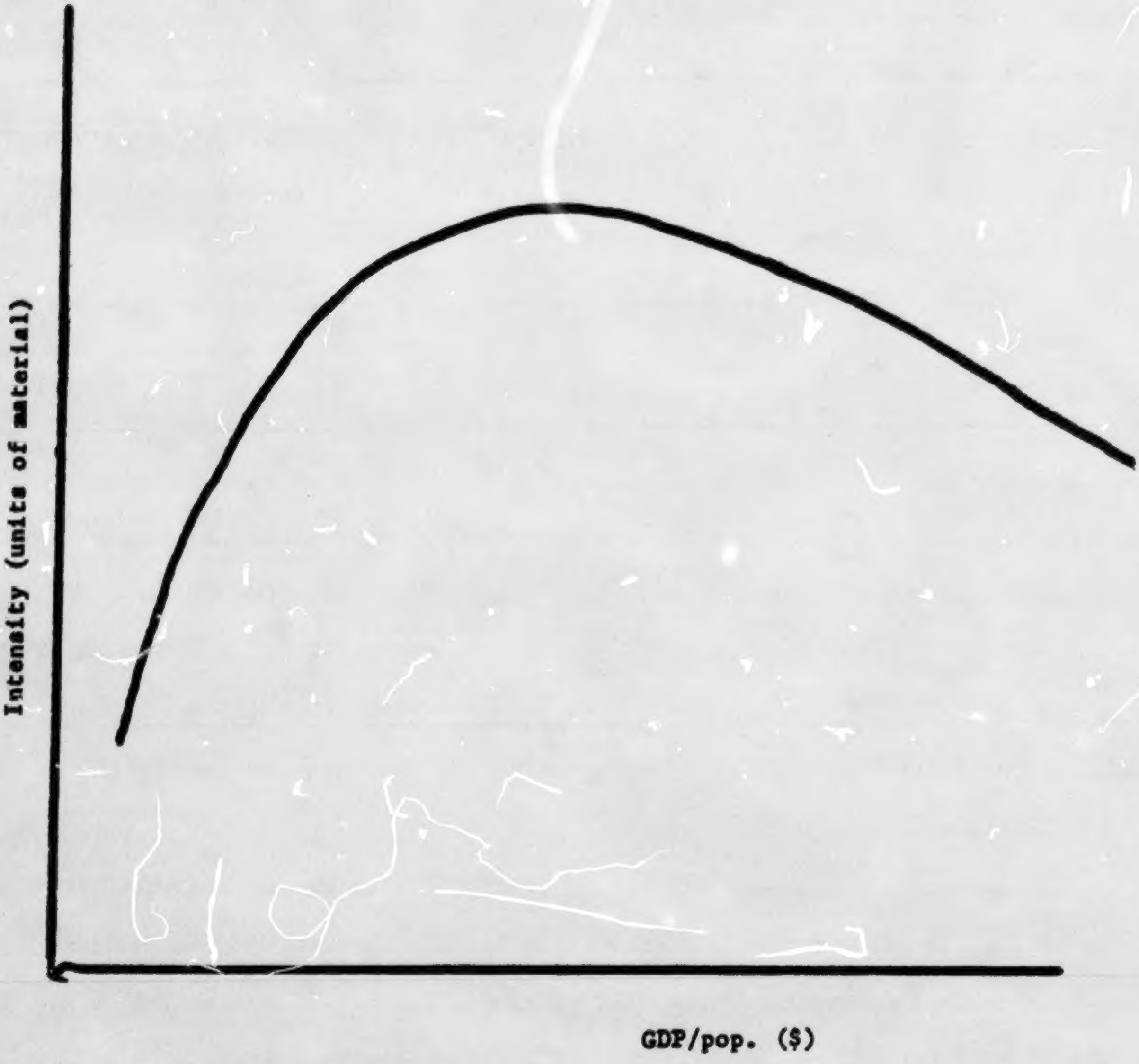
Trends and patterns of past intensity-of-use data were studied; they offer several possibilities for the future. On occasion, the past record suggested a more or less direct extrapolation to 1985 or to 2000. More common was evidence of a reversing pattern with intensities growing over a period and then contracting. There is some evidence of association with per capita income levels. On the whole, intensity-of-use measures for all regions of the world do seem to reveal some systematic patterns. These are discussed below, with special regard to these factors: actual changes in final goods and services (in which the materials are inputs) as per capita income grows; the development of new technologies that make for more efficient materials use; the possibilities of substitution among materials as technology, demand and supply alter relative materials prices. All these and the extensive analytic and descriptive literature on materials use do provide some guides for projecting the appropriate intensity level for 1985 and 2000 (see Figure A-2). As in the case of GDP, economic theory helped also, particularly doctrine on commodity substitution with demand and technological change, and with the price and policy adjustments related to these changes.

In the last analysis, however, systematic consideration of these guides and possibilities needed to be supplemented by the judgment of the research worker. For the present report as in the initial study, this subjective input was the responsibility of one individual, the principal researcher on this project. As with the "answers" for rates of national growth to the years 1985 and 2000, the "answers" on intensity-of-use of each material in those years reflected consistent judgments, conditioned by a vast assembly of pertinent data (and published and other expert opinion), the economic rationale of past performance, and theories of economic equilibrium, change, and growth.

Materials requirements for 1985 and 2000, with comparable statistics on historical use, are treated in section V. The "answers" for the future permit ready comparisons of materials consumption over time and among important subdivisions of the world. They also provide a point of brief departure to questions of supply-demand relationships and to materials-supply and economic growth relationships.

Finally, emphasis must again be given to the truth that the main components of the research program rest on a common basic assumption: the

Fig. 2-2--Intensity-of-Use and GDP per Capita: An Impressionistic Representation



growth of nations has an internal dynamic. That is, long-term growth is not governed by supply limitations of any specific input materials nor is it limited by any inelasticity of total output imposed by supply or demand of materials. This assumption made it possible to project national and world economic growth in one part of the research effort without regard to the materials needs appraised in the other part of the study. A nation meets its needs for materials in the pursuit of its economic, social, and political objectives. This assumption is consistent with the theory of economic growth held to be relevant to experience in the modern world of the past two centuries or so. In addition, the research on past materials consumption, and indeed the results developed below, are themselves testimony to the diversity of materials usage in the modern world. As relative supplies shift, as demands alter, as techniques of use change, as price ratios vary, rules of operation are altered. These adjustments are the tools by which man and society obtain and use materials they need. This is how it has been; the extensive past experience augurs well for the future.

But the tools must cope with what promise to be progressively greater tasks. Poor nations must have higher levels of living; populations grow at record rates; minerals production generates environmental hazards. There is need for continuous and imaginative study of the alternatives in supply and requirements of materials, and for governmental and intergovernmental policy and actions based on such study. Still, the past record tells us that such efforts can be undertaken with the expectation that the world's materials resources can continue to serve the world's aspirations for social and economic progress. The world's materials resources will govern such objectives only if research and policy needs are neglected.

III. World Economic Growth: The Prospect for 1985 and 2000

The record of national growth throughout the world has been subjected to thorough analysis over the past thirty years. Scientific mastery of the determinants of national growth was thought to have been achieved: fiscal and monetary policies, resource and knowledge transfers became commonplace tools, broadly available to nations through a growing body of practitioners in business, public and academic life. This intellectual achievement was even paralleled by an extraordinary growth achievement from mid-century for almost twenty-five years. GDP grew at very rapid rates, seemingly without past parallel, and quite generally throughout the regions of the world. Despite record levels of population growth, output per person moved ahead even in the poor lands, and again without early parallels.

But the miracle faltered. Neither theoretical knowledge nor recent achievement offers today any assured growth prospects for the decades ahead. Despite the impressive overall growth performance in third world lands, careful analytic studies have for some years been suggesting that so-called "quality" inputs were playing a progressively diminished role in national growth. Indeed, poor-nation economies and societies were becoming more dualistic, with widening gaps among labor-intensive and capital-intensive sectors, between an increasing percentage of poor and a small percentage of rich. With such internal developments, these nations were not able to make effective use of their actual productive endowments, nor of the further increments in these resources potentially available to them. Basically national leaders in these lands were not able or not willing to stimulate, in the public or the private sector, greater output per person on the part of the maximum possible segment of their populations.

Note has been made of the contrast in growth forces in the rich and successful lands and in those in the faltering economies of the poor lands, even in the years from 1950 through 1973. But by the mid-1970s the contrast was becoming less apparent. The rich economies were themselves suffering from internal divisiveness, from leadership activities geared to gains of only part of the society. In any event, the present world recession emerges as an economic state not responsive to the growth tools of past decades. In rich as well as poor nations, new tasks await new leadership. New quality inputs that will serve to integrate each national economy are essential if high growth rates are again to be achieved. Supplies of labor, technology and related skills—standard inputs of theories of growth—continue of course to be needed. But historical analyses of actual growth in rich lands on the one side, and of world experience with accelerated development efforts in poor nations over two-three decades on the other, suggest that supplies of the traditional inputs in whatever measure cannot of themselves assure sustained economic progress.

Man and society seem less able to use these standard inputs effectively. This has become apparent in recent decades especially as supplies (including education, technology and skills) have expanded dramatically in most of the world's countries. The poor nations need to engender deeper commitments to economic expansion on the part of workers, so many of whom are essentially self-employed and hence decision-makers. It is necessary that national institutions involve these workers more directly in development activity. The early priorities for government policy need to focus on increments in employment, with emphasis on the compatibility of maximum employment and maximum output goals in what can be characterized as an essentially persistent state of disequilibrium in the economy. These requirements were emphasized with respect to problems of poor-nation growth in the 1973 report, but the current economic outlook for the world's rich lands calls for a similar emphasis. Underutilized people and underutilized capital facilities and underutilized technological knowledge and skills defy efficient use; institutional changes and new operational systems need exploration, testing and implementation. The quality of leadership over the next decades will be the fundamental determinant of the economic progress.

Unhappily, the operational course to that end is not straightforward. The gross product outlook for 1985 and 2000 cannot be any mechanical extrapolation of the record of the past twenty-five years or so. The rates of future growth offered here for the next decade and for the turn of the century reflect judgments on the extent to which new and different economic and social policies will in fact dominate in the various regions of the world. Similar considerations prevailed in NCMP'1973, but developments over the intervening years prompt a greater respect for the difficulties that must now be overcome.

The actual growth rates (to 2000) used in the present report differ for the most part from those applied in NCMP 1973. On the whole, the persistent development problems in the rich lands over the past four-five years altered in some degree the earlier growth expectations for the rich relative to the poor categories of nations. It is true that implementation of programs for quality inputs has long-term roots in the developed lands. But the need to shift to an employment emphasis poses difficult decisions in these capital-intensive economic structures. Nor can progress in the poor nations be dramatic, however great the development potential such activities can promise. And poor-nation preoccupation with old formulas on economic development may at best offer occasional short-term gains and limited long-term growth benefits. So, pending pursuit of new development strategies, GDP average growth rates are expected to have low levels relative to those of the 1951-75 era.

Finally, the projected growth rates reflect the judgment of the principal investigator, with full regard to other research and appraisals available on the current scene with respect to world economic development.

Tables 3-1.1 -3 -1.3 provide estimated rates of growth to 1985 and to 2000 for GDP, population and GDP per person, respectively.

Some historical base data are included in these tables for ready comparison, but further detail for past years are available in Appendix Tables 3-I - 3-III. Corresponding data for actual average levels of GDP, population and GDP per person (U.S. $s, 1971 prices) are given in Tables 3-2.1 - 3-2.3. (Again, Appendix Tables 3 -I - 3-III are more complete on past years.) These are reported for the two major world subdivisions and for the ten world regions. Where NCMP 1973 prepared comparable estimates for the year 2000, these are shown alongside the projections of the present study.

World GDP is shown to be growing at an average rate of 3.5 percent between 1971-75 and 1985, and by 3.3 percent between 1971-75 and 2000. These contrast with an actual rate of 4.7 percent per year from 1951-75. Total real product will thus increase by more than 50 percent from 1971-75 to 1985 and by 150 percent from 1971-75 to 2000. These statistics for world gross product as a whole, and indeed for the U.S.-non-U.S. and for the poor nation-rich nation subgroups of the world, are lower than were the

Table 3-1.1

World GDP, Annual Growth Rates*: 1951-2000

Region	1951-75	1975-85	1975-2000**	
1. W. Europe	4.5	3.3	3.2	(3.5)
2. Japan	9.3	4.2	4.1	(5.0)
3. ODL	4.7	3.4	3.3	(3.75)
4. U.S.S.R.	5.5	3.6	3.4	(4.0)
5. E. Europe	4.9	3.7	3.5	(3.5)
6. Africa	5.1	3.5	3.4	(3.4)
7. Asia	4.9	3.3	3.2	(3.5)
8. L. America	5.6	3.7	3.6	(3.75)
9. China	4.3	3.5	3.3	(4.2)
10. U.S.	3.6	3.3	3.2	(3.8)
Totals				
11. World	4.7	3.5	3.3	(3.8)
12. Non-U.S. World	5.2	3.5	3.4	(3.8)
13. Poor Nations	5.0	3.5	3.4	(3.8)
14. Rich Nations	4.6	3.5	3.3	(3.9)

Source: Table 3-2.1; also see text, section III.

*Annual rates based on 5-year periods; thus 1951-75 refers to 20-year period from 1951-55 to 1971-75.

1975-85 refers to 12.5-year period from 1971-75 to a 5-year period centered at 1985.

1975-2000 refers to 27.5-year period from 1971-75 to a 5-year period centered at 2000.

**Bracketed rates are comparable magnitudes estimated in an earlier study, NCMP 1973 (see text).

Table 3-1.2

World Population, Annual Growth Rates*: 1951-2000

Region	1951-75	1975-85	1975-2000**	
1. W. Europe	0.9	0.8	1.0	(1.1)
2. Japan	1.1	0.9	0.8	(1.0)
3. ODL	2.3	2.0	1.8	(1.3)
4. U.S.S.R.	1.4	1.0	1.1	(1.5)
5. E. Europe	0.8	0.8	1.0	(1.0)
6. Africa	2.4	2.7	2.4	(2.6)
7. Asia	2.5	2.7	2.4	(2.2)
8. L. America	2.9	2.8	2.6	(2.8)
9. China	1.8	1.6	1.4	(1.4)
10. U.S.	1.5	1.0	1.0	(1.2)
Totals				
11. World	2.0	2.0	1.8	(1.8)
12. Non-U.S. World	2.0	2.0	1.9	(1.9)
13. Poor Nations	2.3	2.4	2.1	(1.9)
14. Rich Nations	1.2	1.0	1.0	(1.2)

Source: Table 3-2.2; also see text, section III.

*As earlier.

**As earlier.

Table 3-1.3

World GDP Per Capita, Annual Growth Rates*: 1951-2000

Region	1951-75	1975-85	1975-2000**
1. W. Europe	3.6	2.5	2.2 (2.5)
2. Japan	8.2	3.3	3.3 (4.0)
3. ODL	2.4	1.4	1.5 (2.5)
4. U.S.S.R.	4.1	2.6	2.3 (2.6)
5. E. Europe	4.1	2.9	2.5 (2.5)
6. Africa	2.7	0.8	1.0 (0.9)
7. Asia	2.4	0.6	0.8 (1.3)
8. L. America	2.7	0.9	1.0 (1.0)
9. China	2.5	1.9	1.9 (2.9)
10. U.S.	2.1	2.3	2.2 (2.6)
Totals			
11. World	2.7	1.5	1.5 (2.0)
12. Non-U.S. World	3.2	1.5	1.5 (2.0)
13. Poor Nations	2.7	1.1	1.3 (1.9)
14. Rich Nations	3.4	2.5	2.3 (2.7)

Source: Table 3-2.3; also see text, section III.

*As earlier.

**As earlier.

Table 3-2.1

World GDP: 1951-2000
(Billions of U.S. $, 1971 prices)

Region	1951-55	1971-75	1985	2000**	
1. W. Europe	389	936	1405	2226	(2590)
2. Japan	44	258	431	779	(1070)
3. ODL	73	183	278	447	(490)
4. U.S.S.R.	210	617	960	1547	(1680)
5. E. Europe	86	227	357	585	(575)
6. Africa	26	71	109	178	(185)
7. Asia	77	201	302	478	(680)
8. L. America	67	200	315	529	(620)
9. China	62	144	221	352	(480)
10. U.S.	557	1122	1684	2668	(3135)
Totals					
11. World	1591	3960	6062	9789	(11495)
12. Non-U.S. World	1034	2838	4378	7121	(8360)
13. Poor Nations	232	617	947	1537	(1965)
14. Rich Nations	1359	3344	5115	8252	(9530)

Source: See Appendix Table 3-I; also see text, section III.

**As earlier.

Table 3-2.2

World Population: 1951-2000
(Millions of People)

Region		1951-55	1971-75	1985	2000**	
1.	W. Europe	314	379	419	498	(510)
2.	Japan	87	108	122	133	(140)
3.	ODL	41	64	82	105	(90)
4.	U.S.S.R.	189	250	282	336	(375)
5.	E. Europe	110	130	144	171	(170)
6.	Africa	218	354	493	680	(700)
7.	Asia	726	1199	1672	2301	(2160)
8.	L. America	170	299	422	605	(650)
9.	China	594	852	1038	1248	(1335)
10.	U.S.	160	214	242	281	(300)
	Totals					
11.	World	2609	3848	4916	6358	(6430)
12.	Non-U.S. World	2448	3635	4674	6077	(6130)
13.	Poor Nations	1708	2703	3625	4834	(4845)
14.	Rich Nations	901	1144	1291	1524	(1585)

Source: See Appendix Table 3-II; also see text, section III.

**As earlier.

Table 3-2.3

World GDP Per Capita: 1951-2000
(U.S. $, 1971 prices)

Region		1951-55	1971-75	1985	2000**	
1.	W. Europe	1238	2469	3353	4470	(5059)
2.	Japan	507	2389	3532	5857	(7643)
3.	ODL	1788	2869	3390	4257	(5444)
4.	U.S.S.R.	1106	2469	3404	4604	(4480)
5.	E. Europe	788	1747	2479	3421	(3382)
6.	Africa	120	202	221	262	(264)
7.	Asia	106	168	181	208	(315)
8.	L. America	393	671	746	874	(954)
9.	China	104	168	213	282	(360)
10.	U.S.	3472	5250	6959	9495	(10450)
	Totals					
11.	World	609	1029	1233	1540	(1788)
12.	Non-U.S. World	422	781	937	1172	(1364)
13.	Poor Nations	136	228	261	318	(406)
14.	Rich Nations	1508	2922	3962	5415	(6013)

Source: See Appendix Table 3-III; also see text, section III.

**As earlier.

projections in the 1973 report. If the 1951-75 growth rates were expected to continue, world GDP in 2000 would be shown in the $13-14 trillion range, in contrast to an $11 trillion figure in NCMP 1973 and just below $10 trillion in the present report (Table 3-2.1). Lower rates are considered appropriate broadly through the world. In some small degree they do reflect the later data (1973 through 1976) available for the present report: the scale of world recession exceeded pre-1973 expectations. But, as indicated earlier, the basic reasons for the present projections of significantly lower GDP growth rates stem from the current state of economic growth theory and knowledge. While NCMP 1973 was alert and explicit with regard to new forces in the economic growth process, their nature and strength have taken clearer form over the last five years or so. It seems hard to believe today that only a few years back (during 1965-73, as noted earlier) demand projections for raw materials were based on average GDP growth rates in the 5-6 percent range for a thirty-year time interval. This would have meant a doubling of world GDP each 12-13 years--a five-fold increase. The world estimates of Table 3-1.1 foresee an interval of at least twenty years with an increase below 2.5-fold.

A few additional observations on the 3-2 tables will be helpful. Thus U.S. GDP continues its decline as a share of world GDP, but the rate of decline is significantly smaller in 1975-2000 than in 1951-75. As Table 3-1.1 shows, these postwar decades were marked by appreciably higher GDP growth rates in the non-U.S. world. Special circumstances were contributory here: reconstruction activities in Europe and Japan, the overall conservatism of domestic economic policy in the U.S. In the future, the challenges outlined earlier will confront economic growth efforts in all areas, as

Table 3-1.1 also reveals. The poor nations together have made slow but persistent progress as reflected in their share of world GDP. In 1985 and 2000, the share increasesabove current levels of some 15 percent, but only by a percentage point or so.

Despite the present outlook for lower GDP growth rates, Tables 3-1.3 and 3-2.3 show continued progress in GDP per person for all the world's regions in 1985 and 2000. The average levels in the world's poor nations will continue to decline as ratios of the average levels for the world's rich lands. The data of Table 3-2.3 and of Appendix Tables 3 reveal a significantly better relative growth performance for Mainland China than for the other poor nations together. This is attributed in important measure to growth efforts that serve to enhance labor productivity for very large parts of China's population. No comparable evidence has emerged for very large population groups in other poor regions. With the major differences in population growth rates--past and future in Table 3-1.2--narrowing the gap in per capita product requires significantly higher GDP growth rates in the poor than in the rich nations. This is not considered a likely development over the next decade or even generation.

Note must be made here of the contrast between this last statement and the seemingly much more hopeful possibilities recently announced by the United Nations on the basis of a new study of the world growth outlook.[1] Essentially, this publication presents a prospect for the achievement to 2000 of a very much more rapid rate of GDP growth in all the poor lands taken together. It speaks of annual growth rates for these nations in the 5.5-7.5 percent range, with an overall average (1970-2000) of 6.9 percent or more. This contrasts with the actual 5 percent of 1951-75 and the 3.4 percent projected for 1975-2000 in Table 3-1.1. It also speaks of some slackening in the growth rates of rich nations, to an average of 3.6 percent (as against the 3.3 percent of Table 3-1.1). Mostly the poor-nation acceleration would result from changes in existing political, social and institutional deterrents to economic expansion in these lands, although in some measure it would also benefit from significant increments in new capital inflows somehow sparked by the poor-nation endowment in raw materials. The U.N. deceleration in the rich nation growth rate is presented as the obverse effect of the net transfer of resources to the poor nations.

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[1] The Future of the World Economy, A United Nations Study by Wassily Leontief, et al., New York, Oxford University Press, 1977.

There are important gains to the world in a restructured GDP that generates income flows that are more egalitarian among nations than are current and recent flows. Social and pyschological gains might well exceed whatever economic losses could occur. But there are strong arguments that the noneconomic benefits might actually be accompanied by economic gains; indeed, that maximum economic gains do require some such restructured flow of world GDP. What may be of greater concern than the desirability is the possibility of generating significantly changed international income flows over the next decades. What social, political and institutional adjustments are needed to this end are essentially unspecified in the U.N. study; there is reference to domestic property and income redistribution objectives for the poor nations. Such actions would require a very new and very different approach to the bulk of the population on the part of indigenous leadership and power groups.

Current development emphasis in most of the poor nations draws from the activities of what was called the "Committee of 77" in the U.N., with its focus on the potential economic and political gains from the natural resource endowments of the poor lands. This emphasis actually plays down the fundamental role of internal political, social, institutional and economic impediments to progress. Without a new philosophy on broad participation in action programs within the poor lands, the scope for additional growth gains through capital transfers continues to remain limited. On the other side, it is hard to foresee international transfers over the next decade or so appreciably larger in relative magnitude than have recently prevailed. Nor is this outlook attributable to donor nation concern that larger transfers would reduce the rich world's own rates of GDP growth. For they need not; the fundamental determinants of economic expansion today lie outside any essentially mechanical and material endowment area.

For such reasons the present study has made use of GDP developments summarized in Tables 3-1 and 3-2. They are held to portray realistic orders of magnitude for world economic expansion over the next two-three decades. With these, both the GDP and GDP per capita elements of the demand relationship are in hand. Intensity-of-materials use, the third element, is discussed in the next section of this report.

IV. Intensity-of-Use

The preceding argument has drawn upon relevant theory and observation to establish orders of magnitude for future rates of growth in total product, in population and thus in future GDP per person. These estimates were directed at time spans pertinent to current action for economic and social change: a decade, by 1985 and a generation, by 2000. Estimates for these dates were made separately for each of the ten component parts in which the world is considered here. For reasons explicit in the argument, these future growth rates for total product and per capita product are different, and lower, than were those presented in the 1973 study. Indeed, the present conclusion is that output growth rates over the next two-three decades will average significantly below those prevailing in the decades from 1950-1975. However, the basic thrust of the 1973 argument remains the same: human, quality aspects of the world's societies provide the propelling forces for economic expansion. Judgments on these inputs, not on any quantity of materials inputs, were the decisive elements in the determination of the product figures for 1985 and 2000.

Nonetheless, per capita product is expected to be growing throughout the world over the period to 2000. The average per capita income gap between the rich and poor nations continues to widen absolutely and relatively. And the world continues to aspire to economic progress.

Important quantitative differences are also revealed in the new study with respect to the future levels of the third element basic to the methodology of the present analysis: the intensity of use of raw materials. As indicated in the background section, the present work included a larger number of materials as well as a lengthier time span than did the initial study. These provided an improved base for factual observation. The historical results, average intensity-of-use by five-year periods for each of the twelve raw materials in each regional grouping, are given in Appendix

Tables 4-I to 4-XII. It is the patterns revealed in these data which support projections to generally lower I-U levels than were provided by the information available for the 1973 report.

Again the basic data strongly endorse the earlier argument about the changing "constants" of the relationship between materials use and total output of goods and services. The enlarged body of data also supports the early hypothesis of systematic relationships between intensity-of-use levels in a region and its real per capita product over time. The changing intensity patterns emerge clearly in text Tables 4-1 to 4-12; so also do the I-U, GDP per capita relationships in Figures 4-1 to 4-12. The tables are discussed in broad terms in the following pages. Specific consideration of individual materials then provides greater detail on past data as well as the basis for specific I-U projections. All the considerations underlying this presentation on the I-U variable parallel those provided in the 1973 report.[1] As there, the critical factors lie in the evolving GDP structure of the individual world regions and in the materials substitution/displacement through market and national policy forces, especially under the stimulus of technological developments.

The text tables make clear that for all materials considered here—other than aluminum (9) and with qualification the platinum group of metals (10)—world intensity of use has already reached historical peak levels, mostly a decade or more back. By 1970, these levels were below what had been assumed for that year in NCMP 1973. Moreover, the data through 1975 document declines that had not yet become apparent in the earlier work. It is in these respects that the present study provides strong additional empirical strength to the hypotheses on I-U patterns presented in NCMP 1973.

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[1] NCMP 1973, pp. 9-10 especially.

This inverted-U pattern for the world tends to be revealed even more clearly in the subtotals for I-U in the non-U.S. world and in the rich nations alone. This follows because there actually are two other reasonably distinct I-U patterns in the 1950-75 data for the U.S. and for the poor nations alone. In the former, the turning point in I-U was reached at an early date and for important raw materials (including iron, steel, copper, zinc, tin, among other metals) prior to 1950. The present data seem simply to show persistent I-U declines in the U.S. On the part of the poor nations there is usually the reverse pattern of fairly steady increases in I-U over the period of record here. This last was also inferred from the less complete record in the earlier study. Now, however, there is some evidence of slackening in the growth of I-U in some materials in important developing lands. In contrast to the earlier view in NCMP 1973, the present prospect is that I-U for most materials will not continue to expand in poor nations until high levels of economic development are in fact achieved. Rather, the effects of technological advance elsewhere are spread to them at a relatively early stage of economic growth. This upward I-U thrust from the poor nations was earlier considered some counter to a downward I-U thrust from the rich. The present study takes a somewhat modified general position: the overall force to lower I-U for materials is a stronger one than was suggested in the early work.

In sum, there is for most materials a broad world picture of declining use intensity. A critical component is the position of the U.S., usually the world's primary consumer of materials and from early years the world's predominant industrialized nation. In the U.S. there has long been a persistent downward movement in I-U. Other rich lands reflect the same pattern, with turning points for I-U levels at later dates than in the U.S., perhaps as they reached some specific level of industrial/economic progress. (A per capita GDP level of some 2000 U.S. 1971 dollars was suggested in NCMP 1973.) The tendency to lower I-U levels was also explained in terms of the contribution to that end made by technological progress. The general evidence now is that this factor can begin to be manifest at relatively low-income stages of development through the technology spread from the rich nations. In any event, several important low-income nations demonstrate flattening, if not declining, I-U levels even in the 1970s (and even before any influence from the current world recession). The force of structural change, of substitution/displacement through technological progress can of course expand materials use per unit of GDP. Among the materials studied here, the sole evidence of long-period net increases in I-U are in aluminum and in platinum-group metals. Currently these forces seem also to be a slackening, if not yet a declining element in aluminum I-U...

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